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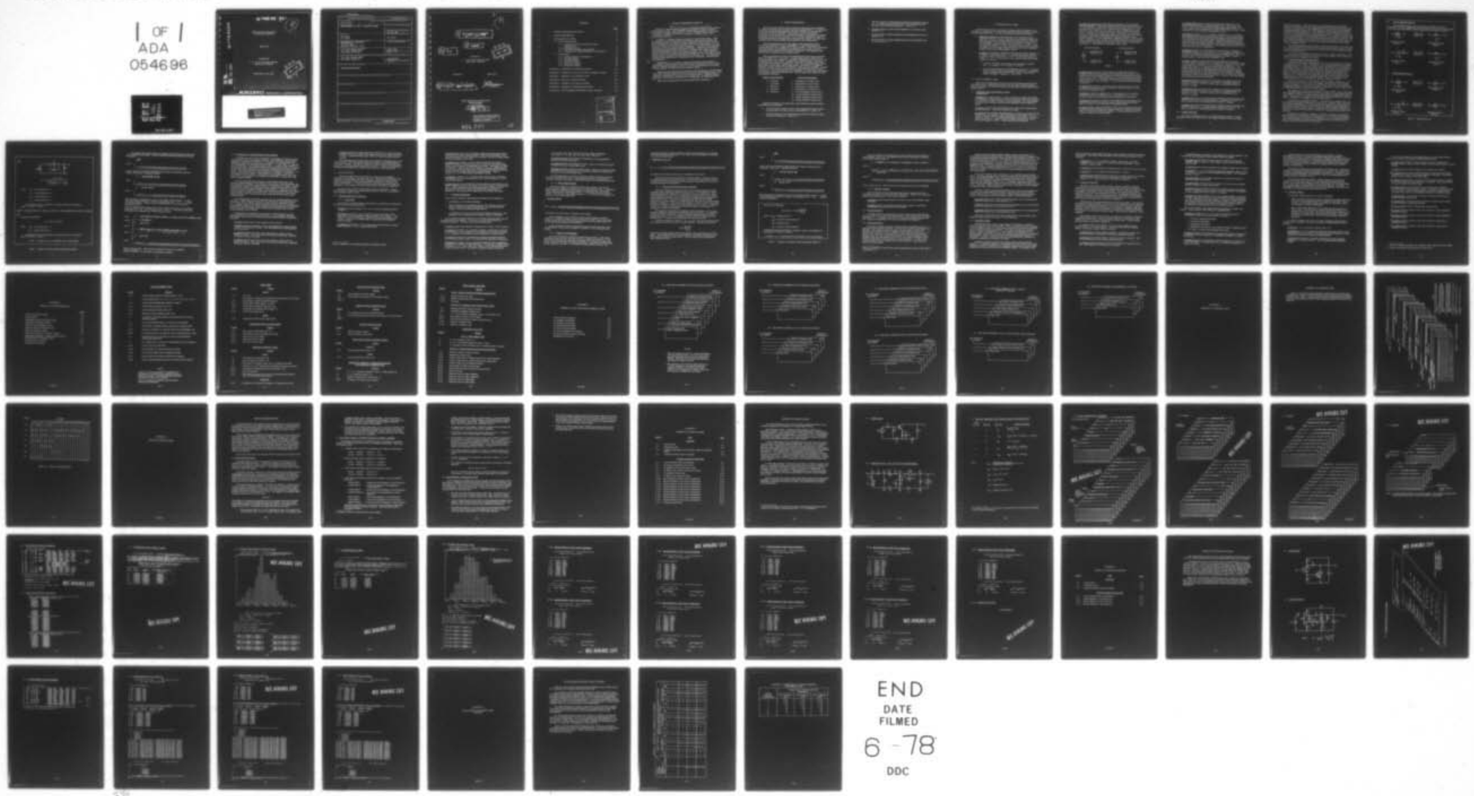

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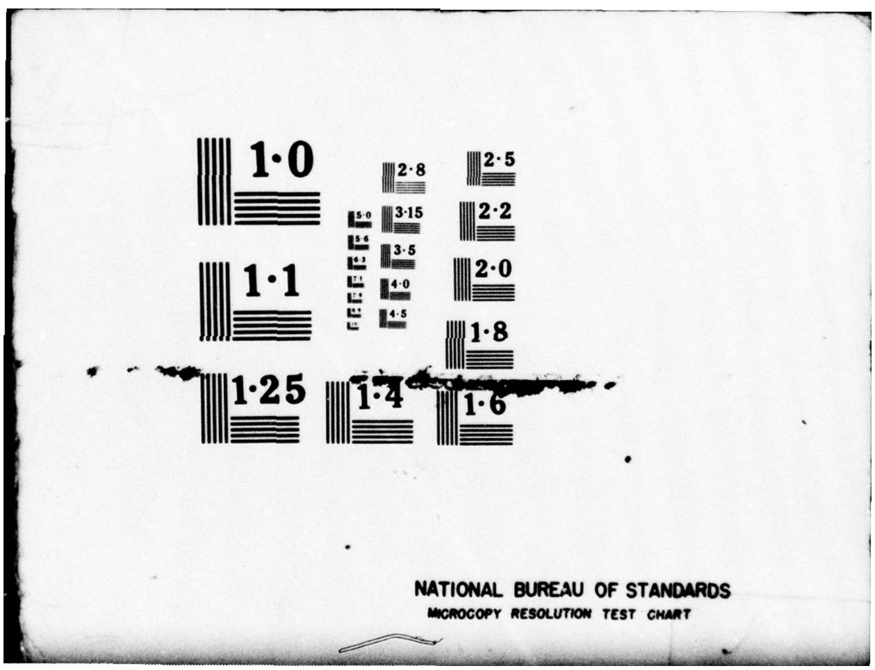
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USER'S MANUAL FOR SNAP II COMPUTER PROGRAM

August 1968

Prepared for

U. S. NAVAL WEAPONS CENTER
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CONTENTS

1. GENERAL DESCRIPTION OF SNAP II

The program is designed, primarily

SNAP II is a computer program primarily designed for solving circuit problems in the frequency domain. ~~This program~~ is characterized by: ~~a)~~ ease of computer programming, ~~b)~~ widely applicable forms of output, ~~c)~~ applicability to various types of computers, and ~~d)~~ the user's ability to exercise all program options with no programming experience.

In general, a computer program is prepared in the following manner. After the equivalent circuit has been determined and each node has been numbered, the circuit element values are entered on cards, together with information concerning limits, distributions, functional relationships with other circuit elements, etc., and the nodes to which each circuit element is connected. From these data the computer establishes the circuit topology and interrelationships. Additional cards define the type of analysis and the format of the output. A specific output request may bear a functional relationship to other circuit elements, outputs, etc. These outputs are computed at any set of specified frequencies including zero (dc) for nominal and other special solutions, sensitivity testing, Monte Carlo analyses, etc. The output may be printed in many different forms, including bode plots, histograms, and specialized data tabulations.

start

Briefly, SNAP II is a computer program incorporating a wide variety of computational subroutines that can be easily used by a nonprogrammer for dc and ac analyses of linear and nonlinear circuits of up to 50 nodes and 200 circuit elements, with any computer of at least 32,000-word storage capacity.

Detailed steps for preparing an equivalent circuit and instructions for preparing each of the cards describing the circuit are presented in the following sections. Also included are examples that exercise all of the analysis options, suggested analysis techniques, instructions for assembling the complete deck, and programming hints. See also the programmer's manual, AD-A054 694.

Page iii lists supplementary information presented in appendices.

2. CIRCUIT PREPARATION

There are no hard and fast rules for deriving an equivalent circuit, though a few specific procedures must always be followed in applying SNAP II. The equivalent circuit must contain discrete elements, the values of which are preferably non-voltage and non-current dependent. If this type of analysis is not possible, subroutines are incorporated for solving specific types of nonlinearities (a complete discussion of which is found in Section 3.1.4). Since such subroutines result in a considerable increase in computer time, piecewise linear analysis--for which many techniques exist--should be applied where possible to avoid nonlinearities.

The circuit elements may have any algebraic interrelationship desired. Current and voltage sources either independent of, or linearily dependent on, circuit-element current or voltage may be used as needed. There are no restrictions on circuit topology, but connecting circuit elements in a long series results in inefficient use of computer time and should be minimized. Any transistor model may be used as long as the above criteria are met.

After the equivalent circuit has been established the nodes must be numbered from 0 to as high as 50, in any order. A number larger than 50 cannot be used. Although numbers may be skipped, 0 must always designate the most common ac and dc electrical node in the circuit. Depending on the type of analysis, each circuit element should be assigned a nominal value, worst-case low and high values, distribution limits, and any other special values needed. Alternatively, an algebraic expression in terms of other circuit elements or values may be substituted. Complex values for circuit elements may also be used and entered directly on the Circuit Element Card. Each circuit element must be identified, for which purpose five spaces are available on each Circuit Element Card. The first space must contain one of the following letter identifiers:

Passive Circuit Elements	Active Circuit Elements
R – resistance	V – independent dc voltage source
C – capacitance	D – independent dc current source
L – inductance	E – independent ac voltage source
A – admittance	I – independent ac current source
Z – impedance	F – current-dependent current source
	G – current-dependent voltage source
	B – voltage-dependent current source
	H – voltage-dependent voltage source

Additional limitations on the equivalent circuit imposed by program storage requirements are listed below.

a. The total number of power sources, except independent current sources for which there is no limit, must be ≤30 (Sections 3.1.1 and 3.1.2).

b. The total number of circuit elements with special value follow-on cards must be ≤30 (Sections 3.1.1 and 3.2.3).

c. **The total number of circuit elements with special distributions must be ≤10. A complex circuit element counts as two non-complex circuit elements for this limitation (Sections 3.1.1 and 3.2.5).**

d. **The total number of complex circuit elements (A or Z) must be ≤50 (Section 3.1.1).**

e. **The total number of EQUIN functional input relationships must be ≤30 (Section 3.1.3).**

f. **The total number of voltage dependent passive circuit elements must be ≤9 (Section 3.1.4).**

3. PREPARATION OF CARDS

The following instructions, also given in summary form in Appendix A, are presented in a manner that will permit an inexperienced analyst to prepare cards for specific programming tasks. He must first acquaint himself with two terms:

a. Right-hand justified means that where there are a defined number of columns on a card to be used for entering a varying number of digits, the digits must be entered so that all blank columns are located to the left of the first integer. For example, if 185 is to be entered in columns 1-6 and right-hand justified, the digits must fill columns 4, 5, and 6. If 185 were entered in columns 1, 2 and 3, the number would be read as 185,000. In addition any group of digits which the manual says must be right-hand justified must also be written without a decimal.

b. E format is the method for entering decimal numbers into the program. It is similar to conventional notation. For example the number 5,000,000 is written in-power-of-ten form as 5×10^6. In E format the number is written "5. E + 06". In general there are two rules to apply when writing a number in E format:

   1) A number must always precede the E and must include a decimal point. For example, 10^{-6} is written as "1. 0E-06".

   2) A number always follows the E indicating the power of 10. It must be right-hand justified and written without a decimal point. Beyond these rules considerable latitude exists. For example, 0. 0025 may be written ". 0025E00", ". 25E-02", "2. 5E-3", etc.

3.1 CIRCUIT ELEMENT CARDS

Each circuit element requires at least one card describing its position and its value in the circuit. Additional information must also appear on these cards for certain output options and will be described in the particular section dealing with the option of interest.

3.1.1 Column-by-Column Description of Circuit Element Card

In columns 1-3 a unique number, 1 to 200, is entered and right-hand justified to identify the circuit element when referenced to other portions of the program. If no reference is needed, columns 1-3 may be left blank. It is recommended that each circuit element be numbered until familiarity with the program is gained.

In column 5 a letter is entered indicating to the computer the circuit element type (see Section 2). This column must have an entry.

In columns 6-9 any additional identifying letters or numbers are entered for the analyst's use. For example, if the circuit element is an inductor, an L is entered in column 5 but its complete identification may be "LS82". The S82 is entered in columns 6, 7, and 8 so that any computer printout of the circuit element will appear as "LS82". These columns may be left blank.

In columns 10-11 and 13-14 circuit element node numbers are entered and right-hand justified. Circuit element nodes should be numbered 0 through 50 in any convenient order, with primary nodes being entered in columns 10-11 and secondary nodes in columns 13-14. Numbers may be skipped but zero must always be used to refer to the most common ac and dc electrical node in the circuit. A number over 50 must not be used. With passive circuit elements the order of node entry is unimportant unless the voltage across or the current through the circuit element determines the output of a dependent source. (Refer to Section 3.1.2 for an explanation of dependent sources.) When entering data for independent active sources, the secondary node is the positive node for voltage sources; and is the node the current is forced into for current sources (see Figure 1). Current flow is conventional, plus to minus.

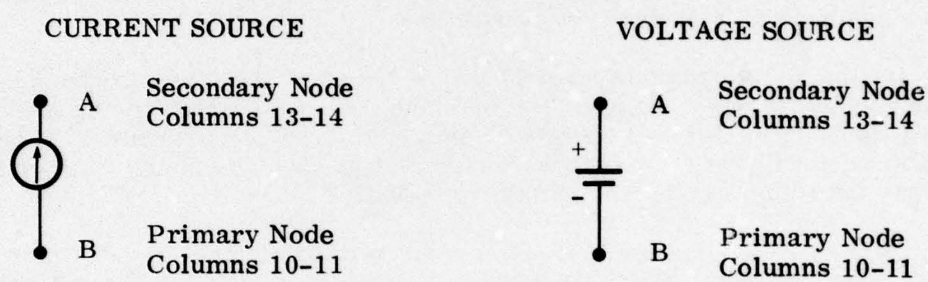


Figure 1

In columns 16-17 a number (1-99) is entered and right-hand justified if a functional relationship expressing the circuit element value is desired. The computer refers to an equation of the same number expressing the circuit element in terms of other circuit elements, etc., rather than the numerical value entered on this card. If a functional relationship is not included the columns must be left blank. Refer to Section 3.1.3 for a discussion of functional input relationships.

In column 18 the numeral 1 is entered if the circuit element is to be varied in sensitivity testing; otherwise it is left blank. Refer to Section 3.2 4 for a discussion of sensitivity testing.

In column 19 a number is entered if the circuit element is to be varied in a Monte Carlo analysis (see Section 3.2.5). The number is a 1, 2, 3, or 4 depending on the circuit element distribution; otherwise it is left blank.

In column 20 the numeral 1 is entered if an additional card with special values follows when specified solutions are required; otherwise it must be blank. Refer to Section 3.2.3 for a discussion of specified solutions.

In columns 21-22 is entered the quantity (1-20) of pairs of numbers required to describe a special distribution for a circuit element in a Monte Carlo analysis These numbers must be right-hand justified. If a special distribution is not required, columns 21-22 must be blank.

In columns 23-25 a number is entered and right-hand justified only if the particular card describes an active dependent source. The number, from 1-200, is the circuit element reference number (appearing in columns 1-3) whose voltage or current determines the output of the dependent source. Refer to Section 3.1.2 for a discussion of dependent sources.

In column 28 a number, 1 or 2, is entered to indicate that 1 or 2 Functional-Input Labeling Cards follow the Circuit Element Card. If the analyst chooses, the Functional-Input Labeling Cards may be omitted and column 28 left blank. The entries made on these card(s) appear immediately following the circuit element listing in the computer printout. Usually the equation describing the functional-input relationship is punched onto the card(s), but any entries may be made in any column the analyst desires. The placement of these cards in the composite deck is shown in Appendix B-1.

In column 30 a number is entered only if the card describes a dependent or independent voltage source. The number, 1-9, is the negative exponent of 10 and equal to the internal resistance in ohms of the voltage source. Thus a 5 in column 30 will set the internal resistance equal to 10^{-5} ohms. Either a blank (no entry) or zero in column 30 specifies 1 ohm.

In columns 31-40 the nominal value of the circuit element is entered in E format. If the circuit element has a complex value it may be entered directly as an impedance or admittance, Z or A respectively, in the form a + jb. The nominal value of the "a" or real part is entered as described above. The nominal value of the "b" or imaginary part is entered in columns 31-40 of a second card and always directly follows the first card of the circuit element describing the real value. This coincidence of real and imaginary values of the two cards exists for all entries in columns 31-80. No entries are required in columns 1-30 of the second or follow-on card. However, it is recommended these columns be used for identification.

In columns 41-50 the circuit element's minimum value (usually worst-case minimum) for sensitivity testing, or any value for a specified solution, is entered in E format. All other comments above concerning the entries in columns 31-40 apply.

In columns 51-60 the circuit element's maximum value (usually worst-case maximum) for sensitivity testing, or any value for a specified solution, is entered in E format. All other comments above concerning entries in columns 31-40 apply.

In columns 61-70 one of the circuit element's statistical values for Monte Carlo analysis, or any value for a specified solution, is entered in E format. All other comments above concerning entries in columns 31-40 apply.

In columns 71-80 one of the circuit element's statistical values for Monte Carlo analysis or any value for a specified solution is entered in E format. All other comments above concerning entries in columns 31-40 apply.

3.1.2 Dependent Sources

Four types of dependent sources are available with this program: current-dependent current and voltage sources, and voltage-dependent current and voltage

sources (see Figure 2). The entries on the Circuit Element Card for dependent sources are the same as those for independent sources except for the circuit element reference in columns 23-25. This additional entry in columns 23-25 is the unique circuit element number (columns 1-3) of the particular circuit element determining the magnitude of the dependent source. The reference circuit element may be an R, L, C, Z, or A. The convention used for referencing the current or voltage in the circuit element to the dependent source is illustrated in Figure 2. For example, in Figure 2a the current flows into node 4, which is entered as the secondary node (column 13-14). The current of the dependent source will flow into node 2 if it is entered as the secondary node. Likewise in Figure 2b, under the same conditions the polarity of the voltage source is positive at node 2.

The voltage dependent sources (Figure 2c and 2d) can be treated in the same manner. When the polarity of the referenced circuit element is positive at node 3, the current of the dependent source flows into node 2 and the polarity of the dependent voltage source is positive at node 2.

The value of the dependent source is the current or voltage (in amperes or volts) of the referenced circuit element, multiplied by one of the entries ("M" in Figure 2) in columns 31-80 of the dependent source card.

3.1.3 Functional Input Relationship (EQUIN)

Functional relationships expressing the value of a circuit element are prepared in FORTRAN IV by the analyst. (FORTRAN IV is a symbolic language for formulating computer instructions. Hints on its usage are given in Appendix D.) The functional relationships may be in terms of numerical values, other circuit elements, frequency, node voltage, and any of the standard mathematical expressions in the FORTRAN library. If reference is made to a node voltage in a functional relationship, a nonlinearity exists by definition in the circuit and extra cards must be prepared (see Section 3.1.4). The functional relationship describing the voltage dependent circuit element must be in terms of only one node voltage. However a maximum of nine voltage-dependent circuit elements may be used for a particular circuit.

Reference to frequency is made with the code word FREQ. Reference to a circuit element is made with the code word CARD(M), where M is the circuit element number in columns 1-3. If a reactive circuit element is referenced, the reference is to reactance and not to inductance or capacitance. Reference to a node voltage is with the code word VOLT(N), where N is the node number.

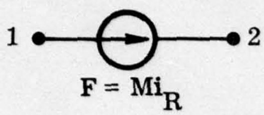
The equations are prepared by assigning a reference number, 1-99, to each equation; writing and right-hand justifying the number in columns 4-5; and entering the code word INPUT in columns 7-11, and an equality sign and then the mathematical relationship in columns 12-72. The equations must be numbered in consecutive order starting with 1. A maximum of 30 equations can be used per circuit.

Consider the two examples in Figure 3. In Figure 3a an ac voltage source, e_{in}, has an internal impedance simulated by R_1, R_2, and C_1. Normally, each circuit element would be input directly. However, perhaps 49 nodes have already been used and the network must still be added; or alternatively, this voltage source might appear several times in the equivalent circuit. In the latter case a significant saving in computer time is possible if many matrix inversions are required (such as in Monte Carlo analysis).

In Figure 3b, resistance R_t depends on a nonlinear relationship involving frequency and two other resistances. If R_1, R_2, R_3, R_4, or C_1 are not circuit elements in the equivalent circuit, their values, distributions, etc., can be entered as if they were circuit elements by entering a zero in columns 11 and 14, provided the total number of circuit element cards is 200 or fewer.

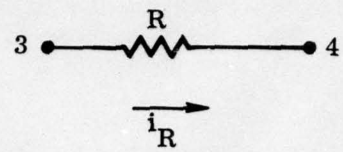
A. <u>Current-Dependent Sources</u>

In each example, nodes 1 and 3 are primary, and nodes 2 and 4 are secondary. M is the multiplication factor in columns 31-80 of the Circuit Element Card, and R_S is the resistance of the voltage source as defined in column 30.

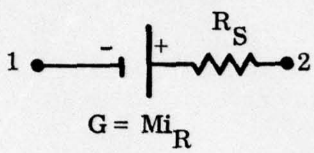


Dependent Current Source

Figure 2a

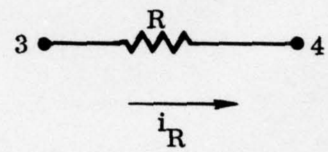


Referenced Circuit Element



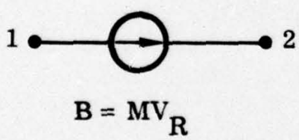
Dependent Voltage Source

Figure 2b



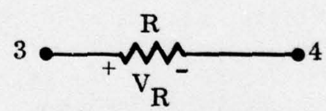
Referenced Circuit Element

B. <u>Voltage Dependent Sources</u>

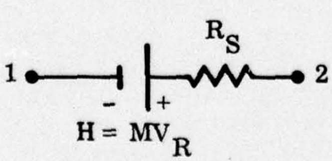


Dependent Current Source

Figure 2c

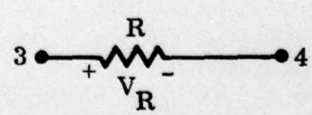


Referenced Circuit Element



Dependent Voltage Source

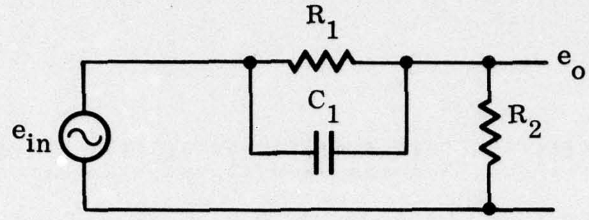
Figure 2d



Referenced Circuit Element

Figure 2. Dependent Sources

3a.



$$e_o = e_{in} \frac{R_2 + 1/j\omega C_1}{\frac{R_1}{R_2}\left(\frac{1}{j\omega C_1}\right) + R_2 + \frac{1}{j\omega C_1}}$$

where e_{in} = circuit element no. 8

R_1 = circuit element no. 10

R_2 = circuit element no. 15

C_1 = circuit element no. 6

Writing this equation in FORTRAN, starting in column 4 and letting e_o equal to "1 INPUT", we have:

1 INPUT = CARD(8)★(CARD(10)+CARD(6))/((CARD(10)/CARD(15))★CARD(6)+CARD(15)+CARD(6))

3b.

Assume the relationship:

$$R_t = (R_3/2\pi f + \ln R_4)^2$$

where R_2 = circuit element no. 13

R_4 = circuit element no. 14

Writing this equation in FORTRAN, starting in column 4 and letting R_t equal to "2 INPUT", we have:

2 INPUT = (CARD(13)/((6.28,0.)★FREQ)+CLOG CARD(14))★★2

Figure 3. Example of Functional Input Relationship (EQUIN)

The equation cards become part of the EQUIN subroutine involving several other cards prepared by the analyst. The first card has the following fixed entry starting in column 1.

Card 1

```
5,5
```

Cards 2 and 3 have statements indicating the total number of equations in the subroutine, in this case 2, starting in column 7.

Card 2

```
      IF(N.GT.2)GO TO 102
```

Card 3

```
      GO TO (1,2),N
```

The last number in parentheses in card 2 is the largest equation number. In card 3 each of the equation numbers is listed in the parentheses (e.g., 1,2,3,.... X, where X is the Xth equation). If there is only one equation there is only one number in parentheses in card 3.

Card 3 is followed by the equation cards, each of which is followed by a card with the statement, GO TO 100. This statement starts in column 7. The equation cards must be assembled in ascending order of their equation numbers.

Card 4

```
    1 INPUT=CARD(8)*(CARD(10)+CARD(6))/((CARD(10)/CARD(15))*CARD(6)+CARD
```

Card 4a

```
     1(15)+CARD(6))
```

Card 5

```
      GO TO 100
```

Card 6

```
    2 INPUT=(CARD(13)/((6.28,0.)*FREQ)+CLOG(CARD(14)))**2
```

Card 7

```
      GO TO 100
```

Card 7 is the last card. This format and spacing must always be maintained.

---

*Refer to Appendix C for description of continuation statement.

3.1.4 Preparation of Voltage Dependent Circuit Elements

A nonlinear circuit for SNAP II is defined as consisting of at least one circuit element whose value is node-voltage-dependent. The relationship expressing this dependency is described in Section 3.1.3. In addition to such relationships, the analyst must supply for each dependent node voltage: 1) a first guess, 2) a high and low voltage limit, and 3) the final desired accuracy. A solution is then obtained by a process of iteration. The maximum number of iterations allowed before convergence to the proper value is determined by the number of dependent node voltages in the circuit. This solution limit is 50 times the number of dependent node voltages. For example, if the circuit consists of four dependent node voltages, a maximum of 200 solutions would be allowed. Convergence may be obtained with far fewer solutions but if it is not reached in 200 solutions the computation is stopped and a diagnostic message is printed.

The ease with which a final solution is reached depends primarily on the number of voltage-dependent circuit elements, the accuracy of the first guesses, and the sensitivity of a particular circuit element to its dependent node voltage. Reaching a final solution becomes more difficult with more complex circuits--those involving more than two or three voltage-dependent circuit elements. Therefore it is in the analyst's interest to establish as closely as possible the actual dependent node voltage for a first guess; to select, for the final value, a level of accuracy no greater than required; and to choose with discretion those circuit elements that must be made voltage dependent.

Four programming restrictions accompany the use of voltage dependent-circuit elements: 1) output requests are limited to DC nominal and DC specified solutions; 2) the number of DC specified solutions is limited to one for each output request (i.e., an output request must be made for each DC specified solution); 3) the functional relationship that expresses the voltage dependent-circuit element must be written in terms of only one node voltage; and 4) a circuit must be limited to nine or fewer voltage dependent-circuit elements.

Programming is accomplished by preparing an EQUIN statement for each voltage dependent-circuit element (per Section 3.1.3), and preparing a Dependent Node Voltage Card for each such voltage associated with each solution, in the following manner:

<u>In columns 4-5</u> the number of the dependent node is entered.

<u>In columns 31-40</u> the approximate value of the dependent node voltage listed in columns 4-5 is entered in E format. This value should be as close as possible to the actual value.

<u>In columns 41-50</u> the lower limit of the value entered in columns 31-40 is entered in E format. This value must be less than the actual value, otherwise convergence may not be reached.

<u>In columns 51-60</u> the upper limit of the value entered in columns 31-40 is entered in E format. This value must be more than the actual value, otherwise convergence may not be reached.

In columns 61-70 the acceptable difference between the true value and the final computed value of the dependent node voltage is entered as a decimal number in E format. A difference of less than 0.002 (0.2%) of the first guess cannot be computed.

These Dependent Node Voltage Cards are assembled in ascending order of node number so that a card indicating the approximate voltage for each dependent node is included in a group. This group of cards (up to nine) is entered in the deck following the Type Card (illustrated in Appendix B.2 and B.4). An entry corresponding to the number of Dependent Node Cards is made in column 17 of the Type Card.

3.2 OUTPUT OPTIONS

The desired output option is described by a group of cards specifying frequencies, node voltages, branch currents, etc. Although many similarities exist among the cards describing each option, complete instructions are given in this section for each option. (Each set of individual instructions is to be used in conjunction with Section 3.2.1, which describes the cards associated with outputs and frequencies.) The assembly of cards for each option is illustrated in Appendix B.

Any option may be used or repeated in any desired combination. However, it is advisable to request only nominal solutions at first to allow for corrections of programming and circuit errors.

3.2.1 Selecting Outputs and Frequencies

3.2.1.1 Type Cards

Each group of cards describing an output option is preceded by two Type cards. The first card has the following format:

In columns 1-2 the code letters AC or DC are entered signifying the type of current.

In column 5 the numeral 1 may be entered to request the printout of the equivalent circuit and admittance matrix generated by the computer.* This option can be used if the analyst is experiencing trouble in getting correct answers. However, it is available only in conjunction with a nominal or specified solution.

In columns 7-8 the number, 1-99, of separate specified solutions is entered. Refer to Section 3.2.3 for a complete description.

*Refer to Appendix C for a further discussion of admittance matrix.

In columns 10-13 a code word is entered to request the output option desired. These words are NOML (nominal solution), SENS (sensitivity testing), SPCL (specified solutions), MONT (Monte Carlo analysis), and PLOT (output plotting). No other abbreviation may be used.

In columns 15-16 a number, 1-99, is entered to indicate the quantity of EQUOUT functional relationships that may be required for this output option. Numbers are not entered if relationships do not exist. All numbers are right-hand justified. When the Monte Carlo analysis or frequency plotting options are used, each output request must be in the EQUOUT-functional relationship format (with node voltages and branch currents included). Refer to Section 3.2.1.5 for a description of the EQUOUT format.

In column 17 a number, 1-9, is entered to indicate the number of dependent node voltages when matrix nonlinearities exist. Refer to Section 3.1.4 for a complete description.

In columns 21-80 any descriptive title for this particular output option may be entered. Where necessary, this title is run over to columns 1-80 of the second card. (A title requiring the use of both cards might be, SMALL SIGNAL DIFFERENTIAL GAIN OF HYBRID DIFFERENTIAL AMPLIFIER 16, MODEL 1A.) The second card is required even if left blank (short title).

3.2.1.2 Selecting Frequencies

There are three methods of specifying the frequencies for computations:

a. Each frequency can be listed separately;

b. The first frequency, the frequency interval, the frequency scale (log or linear), and the total number of frequencies can be specified and the computer compute the individual frequencies; or

c. A combination of a and b can be used where additional frequencies, each specified, will be included with the computer selected combinations.

If the computer-selected frequencies are to increase logarithmically, the rate of progression must be specified. From one to 21 cards will be required for specifying frequencies. The first card has the following entries:

In columns 1-2 the actual number of frequencies to be used (1 to 99) is entered.

In column 10 a numeral, 1-3, is entered to indicate, respectively, that either 1) each frequency will be specified, 2) the frequencies are computer selected, or 3) a combination of frequencies will be specified and computer selected.

In column 20 the numeral 1 is entered if the computer-selected frequencies are to increase linearly, while a 0 or blank indicates logarithmic progression.

In column 25 a numeral, 1 to 3, is entered to indicate the rate of logarithmic progression of computer-selected frequencies. The numeral 1 indicates decade increments (i.e., f_1, $10f_1$, $100f_1$, etc., where f_1 is the starting frequencies entered in column 31-40). The numeral 2 indicates bidecade increments

(i.e., f_1, $3f_1$, $10f_1$, $30f_1$, $100f_1$, etc.); and a 3 indicates tridecade increments (i.e., f_1, $2f_1$, $5f_1$, $10f_1$, $20f_1$, $50f_1$, $100f_1$, etc).

In columns 28-30 the actual number of frequencies to be user specified is entered for the third option above.

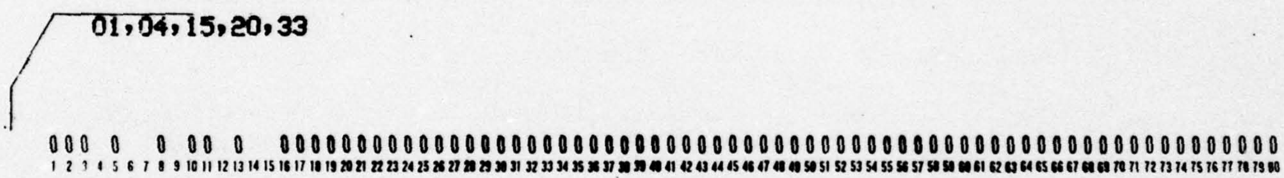
In columns 31-40 the first frequency (in hertz, written in E format) is entered for either the second or third option above.

In columns 41-50 the frequency increment (hertz, written in E format) for linear progression or the final frequency for logarithmic progression is entered for either the second or third option above.

The remaining cards (21 maximum total) have specific frequencies for either the first or the third option above. These frequencies (hertz, in E format) are entered in columns 31-80, with 10 columns per frequency and 5 frequencies per card.

3.2.1.3 Node Voltage Requests

One card is required to request the desired node voltages. If the analyst requires all node voltages, the code word ALL is entered in columns 1-3. Particular node voltages are requested by listing them as two-digit numbers, separated by commas without blanks, beginning in column 4. No deviation from this format is allowed. For example, if the voltages of nodes 1, 4, 15, 20 and 33 are required, the entries are made as indicated below.



A maximum of 25 nodes may be requested in this manner.

If node voltages are not required for either nominal solutions, specified solutions, or sensitivity testing, a blank card must be included in place of the node voltage request card in the card group describing the particular output option (see any card-assembly illustration in Appendix B).

As the computer develops the appropriate equivalent circuit from the circuit element entries, nodes may be eliminated or combined. This is indicated in the printout.

3.2.1.4 Branch Current Requests

One card is required to request the desired branch currents. If the analyst requires all branch currents, the code word ALL is entered in columns 1-3. Particular branch currents are requested by listing the circuit elements through which they flow by their three-digit circuit element numbers, separated by commas without blanks, beginning in column 4. No deviation from this format is allowed. The

computation of branch current is limited to passive circuit elements. For example if the currents in circuit elements 6, 8, 16, 122, and 187 are required, the entries are made as indicated below.

```
006,008,015,122,187

000   0     0   00 000 0000000000000000000000000000000000000000000000000000000000000
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80
```

A maximum of 19 branch currents may be requested in this manner.

If branch currents are not required for nominal solutions, specified solutions, or sensitivity testing, a blank card in place of the branch current request card must be included in the card group describing the particular output option (see any card-assembly illustration in Appendix B).

3.2.1.5 Functional Output Relationships (EQUOUT)

When node voltages or branch currents do not adequately express an output, functional output relationships (EQUOUT) may be used. As with EQUIN the analyst writes the equations in FORTRAN IV expressing the desired relationship. These relationships may be in terms of circuit elements, numerical values, node voltages, branch currents, frequency, and any of the standard mathematical expressions in the FORTRAN library. Reference to frequency is with the code word FREQ. Reference to a circuit element is made with CARD(M), where M is the circuit element number in columns 1-3. Reference to node voltages or branch currents is made with VOLT(N) or CURR(M), where N is the node number and M is as above. If reference is made to a reactive circuit element the element reactance--not inductance or capacitance--is used in computations.

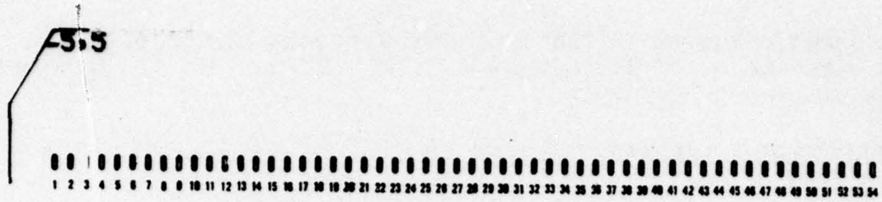
The equations are prepared by assigning a reference number, 1-99, to each equation; writing and right-hand justifying this number in columns 4-5; inserting the code word OUTPUT in columns 7-12; and placing the equality symbol (=) and the equation in columns 13-72. The equations must be numbered in consecutive order starting with 1. A maximum of 50 equations can be used per circuit.

Consider the example in Figure 4. E_{in}, I_{in}, E_{out}, and I_{out} are the appropriate node voltages and branch currents of a power amplifier. The power gain in db is

$$10 \log \frac{E_{out} I_{out}}{E_{in} I_{in}}$$

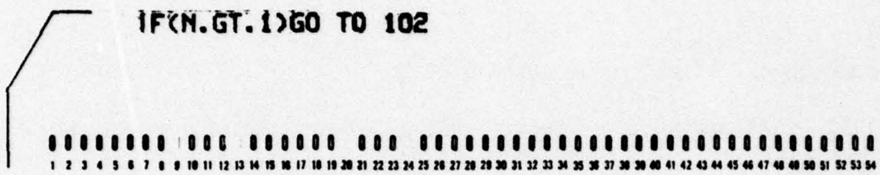
If desired, the plotting option could be selected for a plot of power gain versus frequency. This equation becomes part of the EQUOUT subroutine, involving several other cards also prepared by the analyst. The first card has the following fixed entry starting in column 1.

Card 1

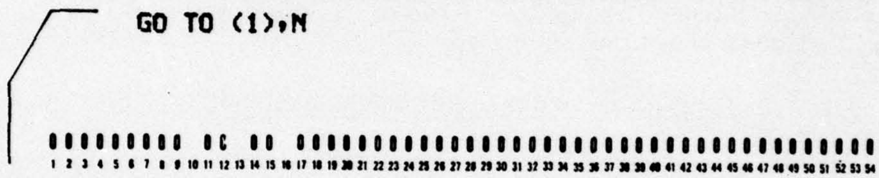


Cards 2 and 3 have statements indicating the total number of equations in the subroutine, in this case 1, starting in column 7.

Card 2



Card 3



The last number in parentheses in card 2 is the largest equation number. In card 3 each of the equation numbers is listed in the parentheses (e.g., 1, 2, 3, ... X where X is the Xth equation).

Assume the relationship:

$$\text{Power Gain} = 10 \text{ Log } \frac{E_{out} I_{out}}{E_{in} I_{in}}$$

where: E_{out} = voltage at node 10

I_{out} = current in circuit element 28

E_{in} = voltage at node 3

I_{in} = current in circuit element 9

Writing the equation in FORTRAN, starting in column 4 and letting power gain equal to "1 OUTPUT" we have:

```
1 OUTPUT = (10.,0.)*CLOG(VOLT(10)*CURR(28)/(VOLT(3)*CURR(9)))
```

Figure 4. Example of Functional Output Relationship (EQUOUT)

Card 3 is followed by the equation cards, each of which must be followed by a card statement, GO TO 100. The equation cards must be assembled in ascending order of their equation numbers.

Card 4

```
  1 OUTPUT=(10.,0.)*CLOG(VOLT(10)*CURR(28)/(VOLT(3)*CURR(9)))

0000000 0 0 0 0 0000000 00 0 000 00 000 00 0000 00 0000000000000
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72
```

Card 5

```
      GO TO 100

000000000 000 00000000000000000000000000000000000000000000000000000000000
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72
```

Card 5 is the last card. The above format and spacing must always be maintained.

3.2.1.6 EQUOUT Labeling

EQUOUT labeling cards provide information that the computer will use in identifying printouts of the output functional relationships. There is one card in this group for each equation card. Each card is as follows:

In columns 1-2 the equation number (in columns 3 and 4 of the equation card) is entered.

In columns 5-12 any combination of letters and/or numbers is entered for identification of the output functional relationship.

3.2.2 Nominal Solutions

A nominal solution is computed from nominal values of circuit elements (the value in columns 31-40 of the circuit element card). After following all of the steps in Section 3.2.1, no additional cards will be required for obtaining a nominal solution. Details on assembling the card group are presented in Appendix B.

3.2.3 Specified Solutions

This option provides a method of selecting specific combinations of circuit element values in computing an output. As many as 99* specific combinations can be requested. The requests for these solutions are made with up to three cards (Specified Solution Request Cards) in addition to those defined in Section 3.2.1. On the first card, columns 1-80 are reserved for circuit elements whose reference numbers are 81-160, and on the third card columns 1-40 are reserved for circuit elements whose reference numbers are 161-200. The number of additional cards required corresponds to the total number of circuit elements; i.e., with 1 to 80 circuit elements one card is needed, 81 to 160 two cards, etc. Only cards with entries are to be included.

---

*Only one combination is allowed when matrix nonlinearities exist per output request. See Section 3.1.4.

The type of entry on these specified solution request cards depends on the composition of the Circuit Element Card. The latter has five fields in columns 31-80 for entering five different numerical values that the circuit element may assume. The fields are numbered 0 (or blank), 1, 2, 3, and 4 for columns 31-40, 41-50, 51-60, 61-70 and 71-80,respectively. If for any reason more than five different values for a particular circuit element are required, a follow-on card may be used for up to five additional values. The values are entered in columns 31-40, 41-50, 51-60, 61-70, and 71-80; and their respective field numbers are 5, 6, 7, 8 and 9. No entries are required for columns 1-30 of the follow-on card, but identifying numbers or letters are recommended.

If the circuit element value is complex (A or Z), one follow-on card already exists. Therefore, two more will be required to specify the five additional values for the real and imaginary parts. They are prepared in the same manner as described above, the only difference being that a field number will refer to two numerical values (real and imaginary) instead of one. For example, reference to field 7 will select the real and imaginary values in columns 51-60 of the third and fourth follow-on cards, respectively. When a follow-on card is used, the numeral 1 must be entered in column 20 of the Circuit Element Card.

Therefore, entries on the Specified Solution Control Cards are the numbers of the fields on the Circuit Element Cards where particular values appear which the analyst wishes to use for a specified solution. These numbers are entered in the columns corresponding to the circuit element numbers, as summarized below.

In columns 1-80 of the first Specified Solution Request Card, the desired field numbers are entered for circuit elements 1-80.

In columns 1-80 of the second Specified Solution Request Card, the desired field numbers are entered for circuit elements 81-160.

In columns 1-40 of the second Specified Solution Request Card, the desired field numbers are entered for circuit elements 161-200.

These sets of cards follow each other in progression, and the number of sets equals the number entered in columns 7-8 of the Type card.

3.2.4 Sensitivity Testing

Sensitivity testing is a means of determining the sensitivity of a particular output to variations of any circuit element. That is, a particular output is computed for the high and low values of a circuit element (columns 41-60 on the circuit element card) for each circuit element separately. Two modes of analysis are possible. Mode 1 provides a less expensive (i.e., less computer time) tabulation for preliminary analyses, and there is no limit to the number of outputs that can be computed simultaneously. Mode 2 provides a more concise tabulation of data (suitable for publication). In Mode 2, worst-case values are also automatically computed, but sensitivity computations are limited to one output.

If sensitivity testing is required, one card in addition to those defined in Section 3.2.1 is needed to indicate 1) the frequencies (as many as five), and whether magnitude or phase is considered for ac sensitivity testing; and 2) the type of output tabulation (two modes) for both ac and dc sensitivity testing. The outputs for this

option are defined by node voltage and branch-current requests and EQUOUT functional relationships. The format of this Tabulation Control and Frequency Request Card is as follows:

In column 5 a 1, 2, or 3 is entered to indicate, respectively, that either magnitude, phase, or both is to be used in sensitivity computation. For dc solution no entry is made.

In column 15 the actual number of frequencies (five or fewer) to be used is entered.

In column 10 a 1 or 2 is entered to indicate mode 1 or mode 2.

In columns 31-80 the frequencies are entered in E format in fields of 10 columns each in a manner identical to that for the frequency entries discussed in Section 3.2.1.2. These columns are left blank for dc analysis.

3.2.5 Monte Carlo Analysis

The Monte Carlo analysis option provides a method of making a statistical assessment of a circuit without rigorous mathematical computations involving the circuit element distribution functions and transfer functions. This assessment is made by assigning a distribution to each circuit element. The computer then randomly selects the value of each circuit element according to the assigned distribution and computes the output(s). When repeated many times, a distribution for the output(s) is formed. The end points of the resulting distribution represent a statistically more valid variation of the output than a worst-case computation.

With this option the analyst defines the boundaries of the output. If a particular sample exceeds these boundaries it is excluded from the histogram and any statistical computations concerning the distribution. If more than 20 percent of the requested samples are beyond these limits the iteration is terminated. In addition to the histogram plot, which is suitable for publication, all pertinent facts about the distribution are tabulated. As many as five separate outputs, each at the same frequency, may be requested.

When planning a Monte Carlo analysis, the analyst must carefully consider the sample size requirements. Generally a large sample size is required for a high confidence level or for accuracy in predicting the sample mean. A table relating these parameters is included in Appendix G.

To request a Monte Carlo analysis, two to six cards in addition to those defined in Section 3.2.1 will be required. The format of the first card (Random Number and Frequency Request Card) is as follows:

In columns 8-10 the actual number of solutions, or sample size 1-999, to be used in the Monte Carlo iteration is entered and right-hand justified.

In columns 11-20 a decimal number, written in E format, is entered. This is the starting value for the random number generator.

In columns 31-40 the frequency to be used in computation is entered in E format. These columns are left blank for dc analysis.

The following card is required for each output (five or fewer) requested. The format of this card (Histogram Format Control Card) is as follows:

In columns 1-2 the EQUOUT equation number is entered and right-hand justified. When the output is a node voltage or branch current columns 1-2 must be blank.

In columns 5-12 the desired labeling for the histogram ordinate axis is entered.

In column 15 a 1, 2, or 3 is entered specifying that magnitude, phase, or both, respectively, is required for the computation of the output. For dc analysis no entry is made.

In columns 22-23, if node voltage is required, the proper node number is entered and right-hand justified.

In columns 25-27, if branch current is required, the proper circuit element number is entered and right-hand justified.

In columns 31-40 the minimum value for an acceptable solution is entered in E format. Any solution below this value will not be included in the histogram or in the computation of mean, median, or variance.

In columns 41-50 the maximum value for an acceptable solution is entered in E format. Any solution above this value will not be included in the histogram or in the computation of the mean, median, or variance. Furthermore if the total number of solutions that fall beyond these limits exceeds 20 percent of the requested sample size, the Monte Carlo analysis for all the outputs is terminated and a partial histogram for each output is printed.

The Circuit Element Cards require special preparation for a Monte Carlo analysis. Entries peculiar to this analysis are stipulated below.

In column 19 a digit from 1 to 4 can be entered to indicate the type of distribution assigned to the circuit element, as follows:

1 = Normal or gaussian distribution.

2 = Log normal distribution.

3 = Rectangular distribution.

4 = Distribution specified by a set of numbers entered on additional cards.

0 (or blank) = Nominal value throughout the analysis.

In columns 61-70 the circuit element's mean value for a normal or log normal distribution, or the low extreme for a rectangular distribution, is entered in E format.

In columns 71-80 the circuit element's standard deviation for a normal or log normal distribution, or the high extreme for a rectangular distribution, is entered in E format.

Columns 61-80 are not used for the Monte Carlo analysis if a special distribution is required. The special distribution data must be cumulative, i.e., the contribution of all data prior to a given point is reflected in the value at the point, rather than its singular value alone. The points describing the distribution should not necessarily be evenly spaced, but should be densest about the area of greatest change. A maximum of 20 pairs of points (40 separate values) may be used to describe the distribution.

The points are entered in E format in fields of 10 columns each. Beginning in columns 31-40 the first cumulative distribution value is entered. In columns 41-50 the uniformly distributed value corresponding to it is entered. In columns 51-60 the second cumulative distribution value is entered, with its corresponding uniformity distributed value in columns 61-70, etc.

Each card has space for five values. Fields on these cards must not be skipped, and only the cards required to contain the pairs of points specified in columns 21-22 of the circuit element card are to be included. If the circuit element has a complex value, twice the number of cards will be required. The values describing the imaginary portion follow the values describing the real portion of the distribution, and are prepared in exactly the same way.

3.2.6 Frequency Plotting

The frequency plotting option has two modes of operation:

a. Mode 1 provides the analyst no options--all decisions concerning the graph are made by the computer based on the variations of the output. This results in a less "finished" graph, but suitable for preliminary analysis and requiring a minimum of preplanning.

b. Mode 2 will provide logarithmic or linear plots of frequency for five or fewer outputs. With this mode the analyst specifies the maximum and minimum values of the output, the number of grid lines for both axes, the labeling for the ordinate axis, and the title for the graph. Output values are always on a linear scale. This mode produces a graph suitable for publication.

To request a frequency plot, two to six cards in addition to those defined in Section 3.2.1 are required. The format of the first card (Mode Request Card) is as follows:

In column 5 a 1 or 2 is entered to indicate mode 1 or 2.

In column 10 a 1, 2, or 3 is entered to indicate for each output whether 1) the output magnitude will be plotted, 2) the output phase will be plotted, or 3) both magnitude and phase will be plotted on separate graphs.

In column 15 the numeral 1 is entered to indicate that for each output the frequency is to be scaled linearly. A zero or blank specifies logarithmic scaling.

For each output requested for the plotting option, one card (Output Selection and Format Control Card) is required with the following format:

In columns 1-2 the EQUOUT equation number is entered and right-hand justified. When the output is a node voltage or branch current columns 1-2 must be blank.

In columns 5-12 the desired labeling for the ordinate axis is entered.

[1,2]In columns 14-15 the number of grid lines in the ordinate direction (parallel to the abscissa) is entered if the output magnitude is requested. This number should be an even multiple of the output range.

[1,2]In columns 17-18 the number of grid lines in the ordinate direction (parallel to the abscissa) is entered if the output phase is requested. This number should be an even multiple of the output range.

[2]In columns 20-21 the number of grid lines in the abscissa or frequency direction (parallel to the ordinate) is entered. This number should correspond in an appropriate manner to the frequencies and frequency range selected. The same scale is used for both magnitude and phase of a particular output.

In columns 22-23, if node voltage is required, the proper node number is entered and right-hand justified.

In columns 25-27, if branch current is required, the proper circuit element number is entered and right-hand justified.

[2]In columns 28-39 the title of this particular plot is entered.

[1,2]In columns 41-50 the minimum value of the ordinate for output magnitude is entered in E format.

[1,2]In columns 51-60 the maximum value of the ordinate for output magnitude is entered in E format.

[1,2]In columns 61-70 the minimum value of the ordinate for output phase is entered in E format.

[1,2]In columns 71-80 the maximum value of the ordinate for output phase is entered in E format.

---

1. When both magnitude and phase are requested, these columns must have entries.
2. Entries are required in these columns for Mode 2 only.

APPENDIX A

SUMMARY OF CARD PREPARATION

CIRCUIT ELEMENT CARD

Column	Entries
1-3	Circuit element program reference number, 1-200
5	Circuit element type: R, C, L, Z, A, V, D, E, I, B, H, F, or G
6-9	Circuit element identification numbers or letters
10-11	Circuit element primary node, 0-50
13-14	Circuit element secondary node, 0-50
16-17	Referenced EQUIN equation number, ≤99
18	The numeral 1 indicates that the circuit element is to be used in sensitivity testing
19	Circuit element distribution (1-4) in Monte Carlo analysis
20	The numeral 1 indicates special values are on a follow-on card
21-22	The pairs of numbers in a specified Monte Carlo distribution, ≤20
23-25	If a dependent source, the reference circuit element number, 1-200
28	The number (0, 1, or 2) of follow-on cards for input functional relationship identification
30	If a voltage source, a number (1-9) specifying the source resistance
31-40	Circuit element nominal value
41-50	Circuit element low value for sensitivity testing
51-60	Circuit element high value for sensitivity testing
61-70	Circuit element mean value for Monte Carlo analysis
71-80	Circuit element standard deviation (1σ) for Monte Carlo analysis

NOTE

Follow-on cards are required for 1) impedances or admittances, 2) additional circuit element values for specified solutions, or 3) values describing a specified distribution for Monte Carlo analysis.

Follow-on cards may be added for input functional relationship identification.

TYPE CARDS

Column	Entries
	Card 1
1-2	AC or DC
5	The numeral 1 requests the equivalent circuit and matrix to be printed
7-8	The number of separate specified solutions
10-13	NOML, SENS, SPCL, MONT, or PLOT
15-16	Total number of EQUOUT equations, ≤99
17	The number of dependent node voltages, ≤9
21-80	Title for this output action
	Card 2
1-80	Continuation of title for this output option

DEPENDENT NODE VOLTAGE CARDS

Column	Entries
4-5	Node number of dependent node, ≤50
31-40	Approximate value of depending node voltage
41-50	Lower limit of node voltage
51-60	Upper limit of node voltage
61-70	Tolerance of node voltage

FREQUENCY REQUEST CARDS

Column	Entries
	Card 1
1-2	Total number of frequencies, ≤99
10	Mode of frequency selection (1-3)
20	The numeral 1 requests a linear scale, 0 requests a log scale
25	A number (1, 2 or 3) indicating the logarithmic frequency increment
28-30	Total number of frequencies to be user selected, ≤99
31-40	The first frequency
41-50	The frequency increment for linear incrementing and the final frequency for logarithmic incrementing
	Cards 2-21
31-80	Frequencies; 10 columns per frequency, 5 frequencies per card

NODE VOLTAGE REQUEST CARD

Column	Entries
1-3	ALL requests every node voltage
4-6, 7-9, ..., 73-75	Node number with comma for each voltage request

BRANCH CURRENT REQUEST CARD

Column	Entries
1-3	ALL requests every circuit element current
4-7, 8-11, ..., 73-76	Circuit element reference number with comma for current request

EQUOUT LABELING CARD

Column	Entries
1-2	EQUOUT equation number
5-12	Title of functional relationship

SPECIFIED-SOLUTION CONTROL CARD(S)

Column	Entries
	Cards 1, 2
1-80	Circuit element field number, 0-9
	Card 3
1-40	Circuit element field number, 0-9

SENSITIVITY TESTING — TABULATION CONTROL AND FREQUENCY REQUEST CARD

Column	Entries
5	A 1, 2, or 3 indicates magnitude, phase, or both; blank for dc
10	A 1 or 2 indicates modes 1 or 2
15	Number of frequencies for this option, ≤5
31-80	Frequencies; 10 columns per frequency

MONTE CARLO ANALYSIS

Column	Entries
	Card 1 – Random Number and Frequency Request Card
8-10	Number of iterations, ≤999
11-20	Random number generator starting value
31-40	Frequency
	Cards 2 to 6 – Histogram and Format Control Card(s)
1-2	Referenced EQUOUT equation number
5-12	Labeling for histogram ordinate axis
15	A 1, 2, or 3 indicates magnitude, phase, or both; blank for dc
22-23	Node number if output is node voltage
25-27	Circuit element number if output is branch current
31-40	Minimum acceptable value
41-50	Maximum acceptable value

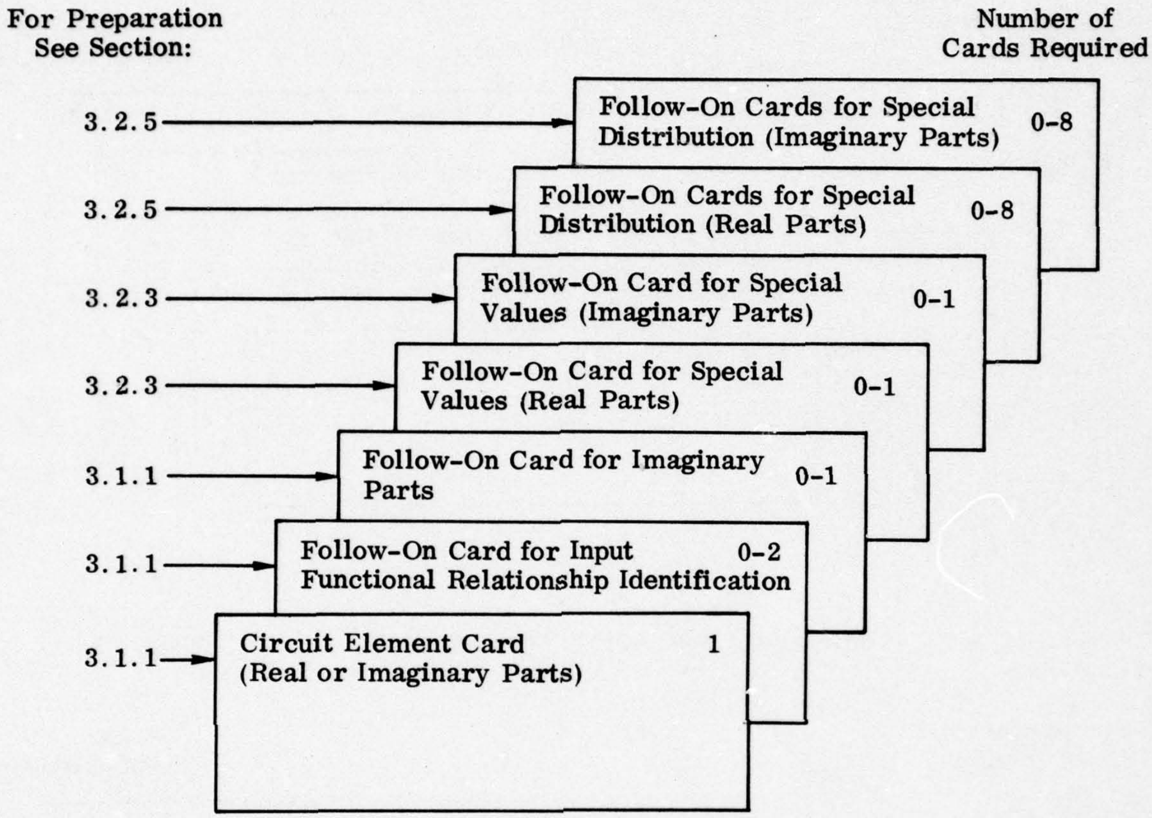
FREQUENCY PLOTTING

Column	Entries
	Card 1 – Mode Request Card
5	A 1 or 2 indicates modes 1 or 2
10	A 1, 2, or 3 indicates magnitude, phase, or both
15	A 1 requests a linear frequency axis, 0 or blank indicates a log axis
	Cards 2-6 – Output Selection and Format Control Card(s)
1-2	Reference EQUOUT equation number
5-12	Labeling for ordinate axis
14-15	Number of grid lines in ordinate direction for output magnitude
17-18	Number of grid lines in ordinate direction for output phase
20-21	Number of grid lines in abscissa direction
22-23	Node number if output is node voltage
25-27	Circuit element number if output is branch current
28-39	Title for the plot
41-50	Minimum value for output magnitude
51-60	Maximum value for output magnitude
61-70	Minimum value for output phase
71-80	Maximum value for output phase

APPENDIX B

ASSEMBLY OF DATA AND OUTPUT REQUEST CARDS

B.1 CARD GROUP ASSEMBLY FOR EACH CIRCUIT ELEMENT

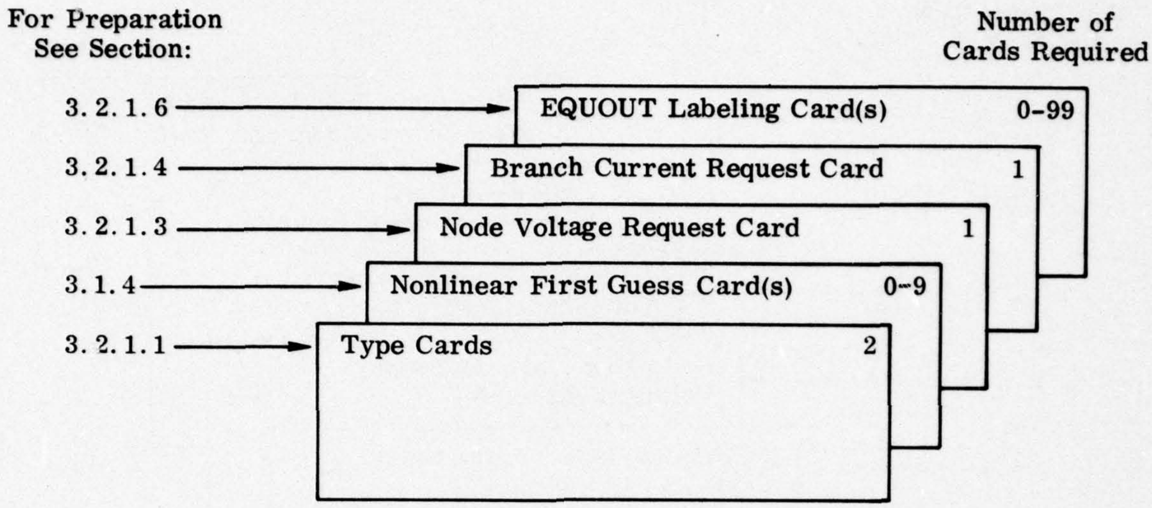


NOTES

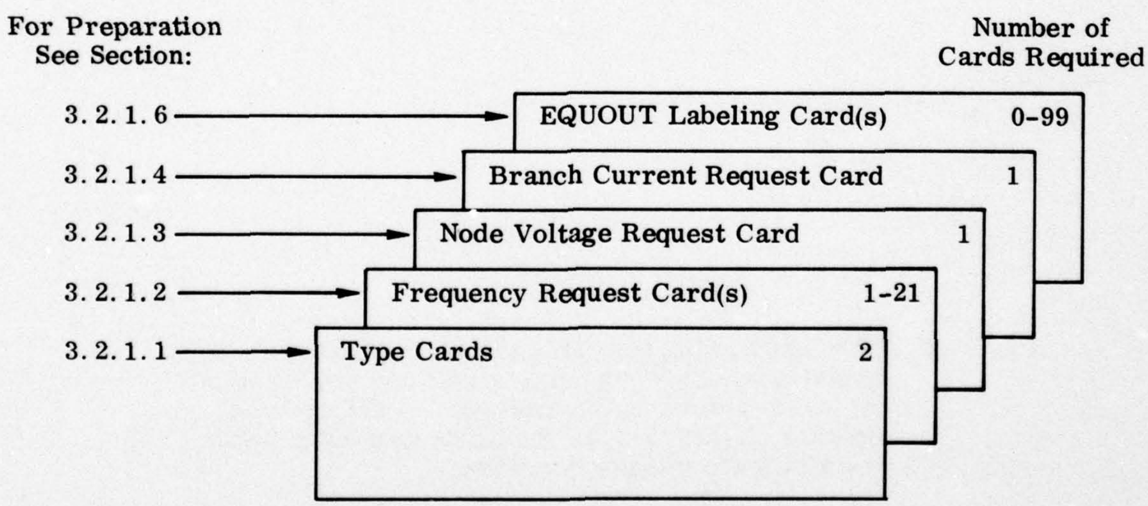
1. When assembling the cards for a special distribution involving complex numbers, all of the cards containing points describing the real portion are grouped together, followed by all the cards containing points describing the imaginary portion.

2. When numbers are not complex (either wholly real or wholly imaginary), the cards describing the imaginary portions are excluded and all values whether real or imaginary are entered on the cards above which are indicated for real values.

B. 2 CARD GROUP ASSEMBLY FOR DC NOMINAL SOLUTIONS



B.3 CARD GROUP ASSEMBLY FOR AC NOMINAL SOLUTIONS



B.4 CARD GROUP ASSEMBLY FOR DC SPECIFIED SOLUTIONS

For Preparation See Section:	Card	Number of Cards Required
3.2.3	Specified Solution Control Card(s)	1-297
3.2.1.6	EQUOUT Labeling Card(s)	0-99
3.2.1.4	Branch Current Request Card	1
3.2.1.3	Node Voltage Request Card	1
3.1.4	Nonlinear First Guess Card(s)	0-9
3.2.1.1	Type Cards	2

B.5 CARD GROUP ASSEMBLY FOR AC SPECIFIED SOLUTIONS

For Preparation See Section:	Card	Number of Cards Required
3.2.3	Specified Solution Control Card(s)	1-297
3.2.1.6	EQUOUT Labeling Card(s)	0-99
3.2.1.4	Branch Current Request Card	1
3.2.1.3	Node Voltage Request Card	1
3.2.1.2	Frequency Request Card(s)	1-21
3.2.1.1	Type Cards	2

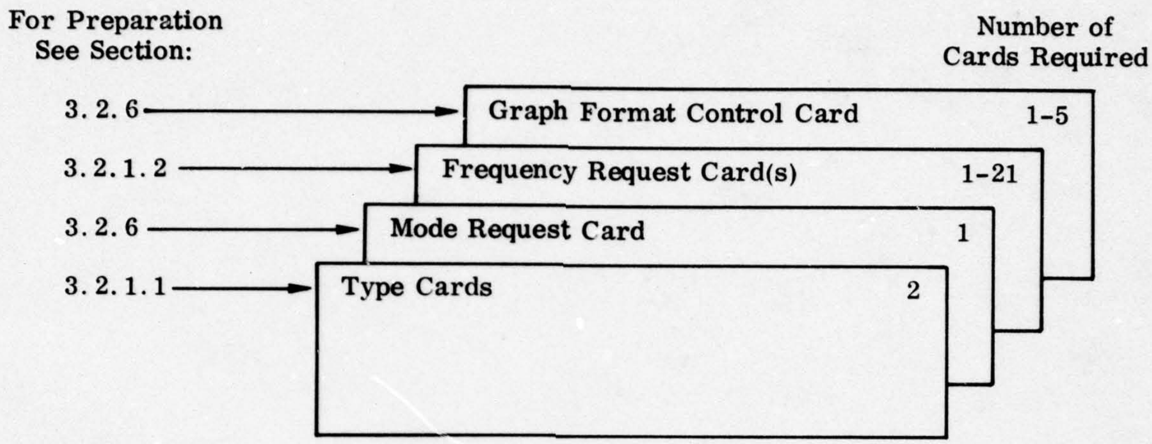
B.6 CARD GROUP ASSEMBLY FOR AC AND DC SENSITIVITY TESTING

For Preparation See Section:		Number of Cards Required
3.2.1.6	EQUOUT Labeling Card(s)	0-25
3.2.1.4	Branch Current Request Card	1
3.2.1.3	Node Voltage Request Card	1
3.2.4	Tabulation Control & Freq. Request Card	1
3.2.1.1	Type Cards	2

B.7 CARD GROUP ASSEMBLY FOR AC AND DC MONTE CARLO ANALYSIS

For Preparation See Section:		Number of Cards Required
3.2.5	Histogram Format Control Card(s)	1-5
3.2.5	Random Number & Freq. Request Card	1
3.2.1.1	Type Cards	2

B.8 CARD GROUP ASSEMBLY FOR FREQUENCY PLOTTING



APPENDIX C

ASSEMBLY OF COMPOSITE DECK

ASSEMBLY OF COMPOSITE DECK

Figure C-1 indicates the exact placement of each card or card group in the composite deck. Figure C-2 lists the entries on these cards that are not explained elsewhere in this manual. The placement of entries on each card and the position of each group must be followed exactly, unless indicated otherwise in the notes below Figure C-1.

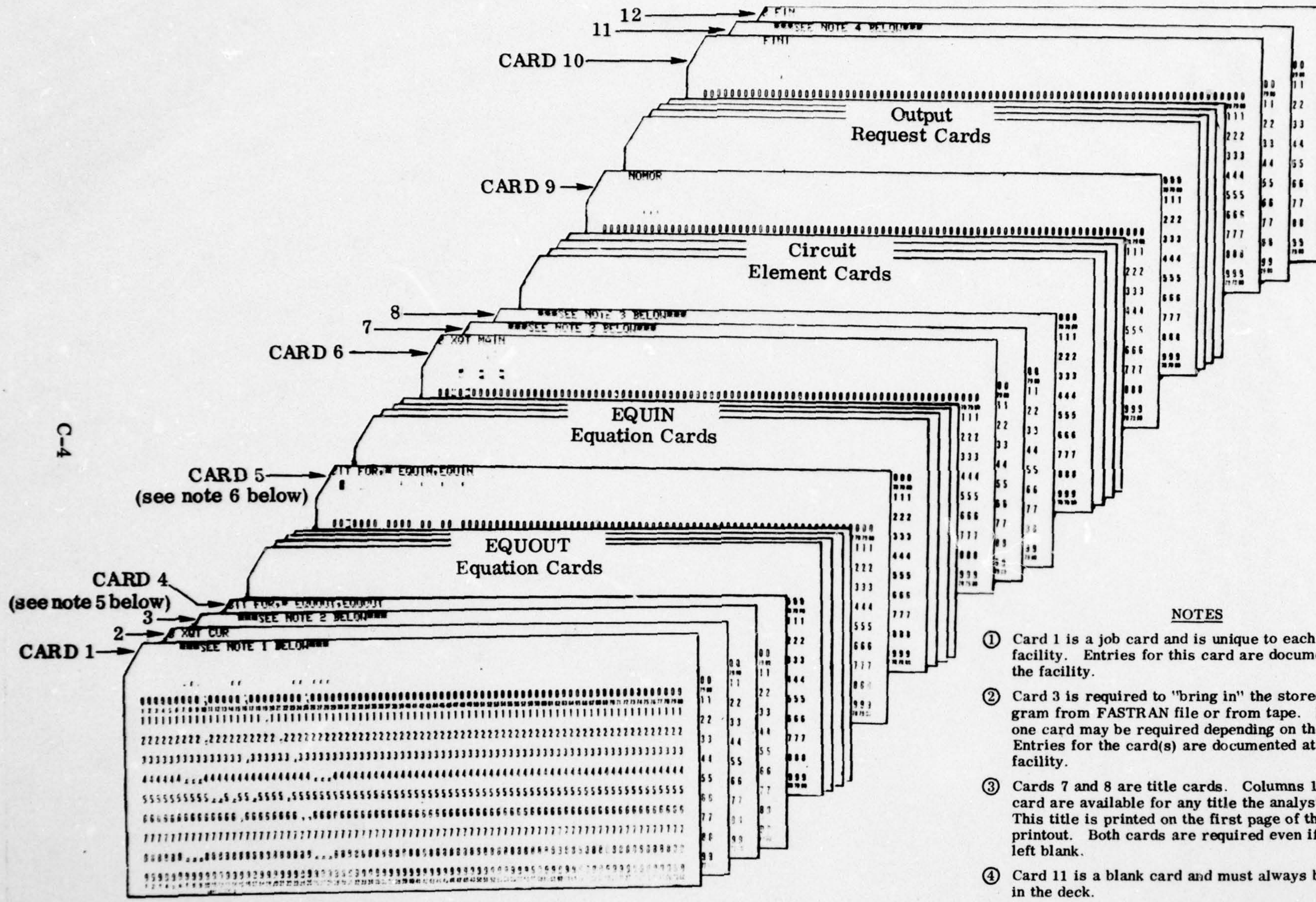


Figure C-1. Composite Card Deck

NOTES

① Card 1 is a job card and is unique to each computer facility. Entries for this card are documented at the facility.

② Card 3 is required to "bring in" the stored program from FASTRAN file or from tape. More than one card may be required depending on the facility. Entries for the card(s) are documented at the facility.

③ Cards 7 and 8 are title cards. Columns 1-80 of each card are available for any title the analyst wishes. This title is printed on the first page of the Computer printout. Both cards are required even if they are left blank.

④ Card 11 is a blank card and must always be inserted in the deck.

⑤ If there are no EQUOUT equation cards, card 4 is omitted.

⑥ If there are no EQUIN equation cards, card 5 is omitted.

CARD	COLUMN																						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	80
#2	7_8		X	Q	T		C	U	R															
#4	7_8	I	T		F	O	R	,	*		E	Q	U	O	U	T	,	E	Q	U	O	U	T	
#5	7_8	I	T		F	O	R	,	*		E	Q	U	I	N	,	E	Q	U	I	N			
#6	7_8		X	Q	T		M	A	I	N														
#9					N	O	M	O	R															
#10										F	I	N	I											
#12	7_8		F	I	N																			

Figure C-2. Entries on Individual Cards

APPENDIX D

HINTS ON COMPUTER USAGE

HINTS ON COMPUTER USAGE

If you are unfamiliar with computers you can expect about two weeks of difficult work preparing your circuit for SNAP II computer programming. This appendix will discuss how to cut down on the preparation time by pointing out some of the common, time-wasting errors in using SNAP II. Many of these rules also hold for other engineering-aid computer programs.

If the computer can be thought of as having human traits, it is like a person who believes that virtue resides in an attention to details. The computer wants only specific details — it has no use for abstractions, ideals, or ultimate goals. Further, like any person totally committed to details, the computer is perfectly capable of carrying out elaborate calculations on erroneous data if it does not catch the initial error. Thus, extreme care should be taken that the initial data are correct and that the computer is not left unsupervised for long periods of time. There should be as many error checks as possible on the input data; and as a further precaution, short runs for nominal solutions should precede computer runs requesting sensitivity or Monte Carlo solutions.

The three common errors in preparing a SNAP II program are discussed below.

(1) Errors in Numeric Inputs

All integers must have their least significant digit in the rightmost column specified by the manual directions. A typical error might occur as follows: columns 1-2 are to contain the equation number of the specified solution and the analyst puts a single digit (say 8) in column 1. The computer will read columns 1 and 2 as 80 and look for that equation.

Frequently an integer misplaced in a column will destroy the sequence of cards following the erroneous card. In this case, the computer will print the diagnostic, INTERPRETATION OF MEANINGLESS INPUT WAS ATTEMPTED. The card image printed after this warning is not the card with the integer mispunched on it, but is likely to be one quite a bit further on in the data deck. Thus the analyst should check preceding cards when this diagnostic is obtained.

All decimal numbers are written in "E format" for SNAP II. E format includes two parts, similar to standard notation. The first part is a mathematically signed decimal number written with a decimal point. (If no sign is present, the computer assumes the number is positive.) The second part of the number is an exponent part similar to 10^2 or 10^{-2}, but written E+2, or E-2. For example, if the analyst wishes to enter the value 283.67×10^2, he writes:

283.67E+2

The number 2 (or whatever the exponent may be) is an integer and must be adjusted to the rightmost column of the field allowed for this number. If one space is left between the last digit and the rightmost column the computer will assume that the exponent part is E+20. Two things can happen when this error is made:

a. If the exponent integer is 3 or less (regardless of sign), the computer will use this number and, if it is on a Circuit Element Card, will probably obtain

a singular matrix* when a solution is attempted. SNAP II will print a diagnostic to this effect. If the number is a frequency or limit on the computation, the computer will probably continue through the requested solutions and obtain erroneous voltage outputs.

b. If the exponent is a number larger than +3 or -3, and was mispunched, the computer will print a diagnostic that indicates the number is too large or too small for the capacity of the computer. Some computers will stop at this point; others will use the largest or smallest number they can manage and will proceed with the computations.

(2) <u>Incorrectly Writing the FORTRAN Statements for EQUIN or EQUOUT</u>

If the analyst is unfamiliar with FORTRAN rules, he should get a beginner's manual on FORTRAN and read the section on Arithmetic Expressions. Some rules and examples follow:

a. Constants must be enclosed in parentheses and written in complex form:

```
Wrong:    OUTPUT = VOLT (1) + .237
Correct:  OUTPUT = VOLT (1) + (.237,0.)
```

b. Operational signs must be separated by parentheses:

```
Wrong:    OUTPUT = VOLT (1) * - CARD (3)
Correct:  OUTPUT = VOLT (1) * (-CARD (3))
```

c. Whole-number exponents must not be followed by a period:

```
Wrong:    OUTPUT = VOLT (1) **2.
Correct:  OUTPUT = VOLT (1) **2
```

d. Preprogrammed functions available to the engineer from the FORTRAN library are

CABS(CARD(1))	=	magnitude of the impedance of circuit element 1.
CEXP(CARD(1))	=	complex exponential of the impedance of circuit element 1.
CLOG(CARD(1))	=	natural log of the impedance of circuit element 1.
LOGTEN(CARD(1))	=	log of base 10 of the impedance of circuit element 1.
CSIN(CARD(1))	=	sine of the impedance of circuit element 1.
CCOS(CARD(1))	=	cosine of the impedance of circuit element 1.
CSQRT(CARD(1))	=	square root of the impedance of circuit element 1.

Arithmetic expressions may be contained in the parentheses which establish the arguments of the above functions. Sines and cosines will be expressed in radians.

---

*A singular matrix is one whose answers are not unique.

Further, the analyst can define a complex number, or reference the real and imaginary parts of a complex number, by using the functions CMPLX, REAL, or AIMAG, respectively. These last three functions are defined under "Built-in Functions" in any FORTRAN manual.

e. All numbers used in the EQUIN or EQUOUT equation must be written with a decimal point, except for whole-number exponents.

f. The number of the equation must be put in columns 4 and 5. It must be a value of 99 or less, written without a decimal point.

g. If the equation is too long to fit on one card, stop in column 72 (columns 73-80 must never be used for FORTRAN equations), put a 1 in column 6 of the next card, and continue writing the equation. This equation can be continued onto any number of following cards. Any symbol can be used in column 6 to indicate a continued equation, but most programmers like to number their continuation cards "1, 2, 3----------".

h. If the engineer begins his equation in column 6, or before column 7, the computer will think this equation is a continuation card of the preceding card.

i. Complex constants or pure imaginary constants are written (1., 2.) or (0., 2.), respectively.

j. Each EQUOUT and EQUIN program should contain a statement of the following nature:

```
IF(N.GT.6) GO TO 102
```

where 6 (or whatever number applies) is the total number of special solution equations or functional input equations appearing in the subroutine.

(3) Out-of-Sequence or Missing Data Cards

Out-of-sequence or missing data cards will usually cause the computer to print the message, INTERPRETATION OF MEANINGLESS INPUT WAS ATTEMPTED, and then print a card image of some of the analyst's data that was placed in the deck after the missing data. The card printed may be several cards removed from the missing card, depending on which card was omitted. Certain cards more likely to be left out than others are discussed below.

a. The first two cards of the data deck are title cards. If the title can fit on one card, a blank card follows the title card. Also, after every output request (Type card), a follow-on title card or blank card must be present.

b. A and Z components must have follow-on cards giving their imaginary parts. Further, if they require special values or special distribution cards, they must have twice as many cards as real components would require.

c. The number in columns 15-16 of the Type card corresponds exactly to the number of EQUOUT functional relationships that must follow the Type card (after intervening frequency or other output requests).

d. Even if node voltage or branch current is not required, blank cards must be in the position in the output deck that would have been occupied by node voltage and branch current requests. The two exceptions to this are frequency plot and Monte Carlo output requests, which do not allow output selections to use node voltage and branch current options.

e. Finally, care must be taken that the NOMOR card appears after the last component card, and that the FINI card followed by a blank card are the last of the data deck.

APPENDIX E

EXAMPLE OF LINEAR ANALYSIS

EXAMPLE OF LINEAR ANALYSIS

This example illustrates the use of each option available with SNAP II, and indicates an approach to the analysis of a common type of circuit.

The illustrative circuit, a common-emitter amplifier, functions as a logarithmic amplifier. The transistor has a steady-state bias of 1.1 milliampere. The input signal is a negative-going pulse of 1-microsecond width, with a maximum amplitude large enough to swing the collector current from 1.1 to 0.1 milliampere. The emitter is completely bypassed. As a result the output is the log of the input derived from the transfer characteristic of the transistor.

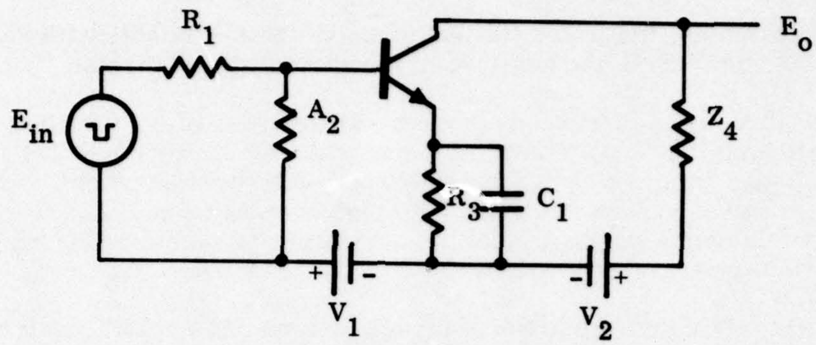
At first it might appear that a meaningful analysis would require the solution of polynominals with variable dependent coefficients. However, such an approach would be costly, requiring excessive computer time and man-hours. Instead a piecewise linear analysis may be conducted so that differences in gain (the required goal) over the transfer characteristic can be accurately predicted for a large number of amplifiers. To accomplish this, circuit elements of the equivalent circuit (R_B, R_E, etc.) are written in terms of empirically derived expressions involving current and temperature. These experimentally determined equations are valid for frequencies from dc to 20 megahertz (1/20 the transistor cutoff frequency), collector current variations from 1.1 to 0.1 milliampere, and temperature variations from -50° to +70°C.

To determine variations of the gain characteristic, the method of analysis will require: 1) sensitivity testing of the steady-state collector current, 2) Monte Carlo analysis of the steady-state collector current with worst-case temperature and component variations, 3) sensitivity testing of the gain at 1.1 milliampere*, and 4) a Monte Carlo analysis of gain at 1.1 milliampere with worst-case temperature and component variations and using the distribution for collector current obtained from 2) above.

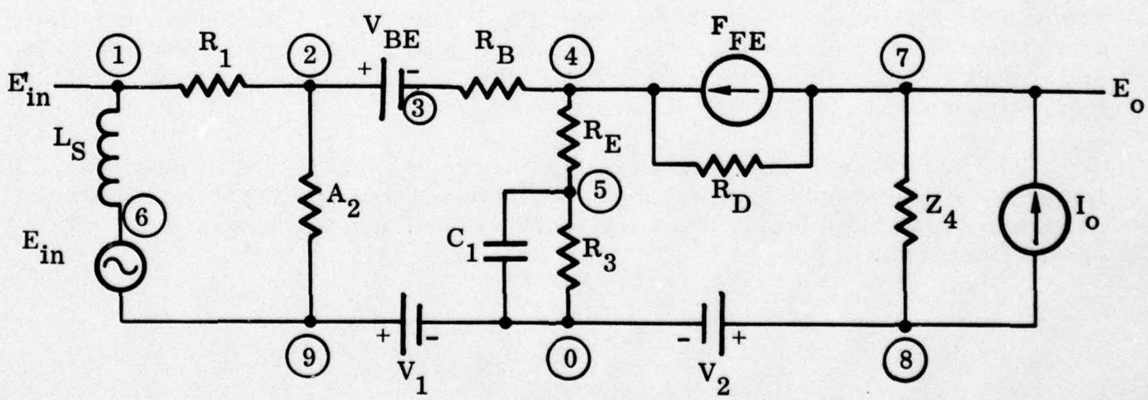
The analysis will also include computing the nominal values of input and output impedances, a frequency plot of gain in db (useful in determining if the amplifier bandwidth is adequate for the input wave-shape), and specified solutions of gain versus temperature.

*To define the transfer characteristic the analysis would normally include several points over the collector current range from 1.1 to 0.1 milliampere.

E. 1 Actual Circuit



E. 2 Equivalent Circuit - From DC to 0.05 of Cutoff Frequency



E.3 Equations Expressing Circuit-Element Values in Equivalent Circuit

EQUIN Eq. No.	Ref. No.	Ckt. Des.	Empirical Equation
1	8	R_E	$\frac{R_{K1}(273 + R_T)}{I_C}$
3	10	F_{FE}	$R_{K3}(0.8335 + 0.00667R_T) + 12.0 \ln I_C$
4	11	R_B	$(1.0 + F_{FE})\, R_E$
5	12	R_D	$\frac{R_{K4}(1.8335 - 0.00667R_T)}{I_C}$
6	21	V_{BE}	$R_{K5}(1.2835 - 0.00307R_T)$

where:

$$R_{K1} = \left(\frac{\text{Boltzmann's Constant}}{\text{Charge on an Electron}}\right)(0.99 \text{ to } 1.01)^*$$

$R_{K3} = h_{FE}$ @ 1 mA, +25°C;

$R_{K4} = r_d$ @ 1 mA, +25°C;

$R_{K5} = V_{BE}$ @ 25°C;

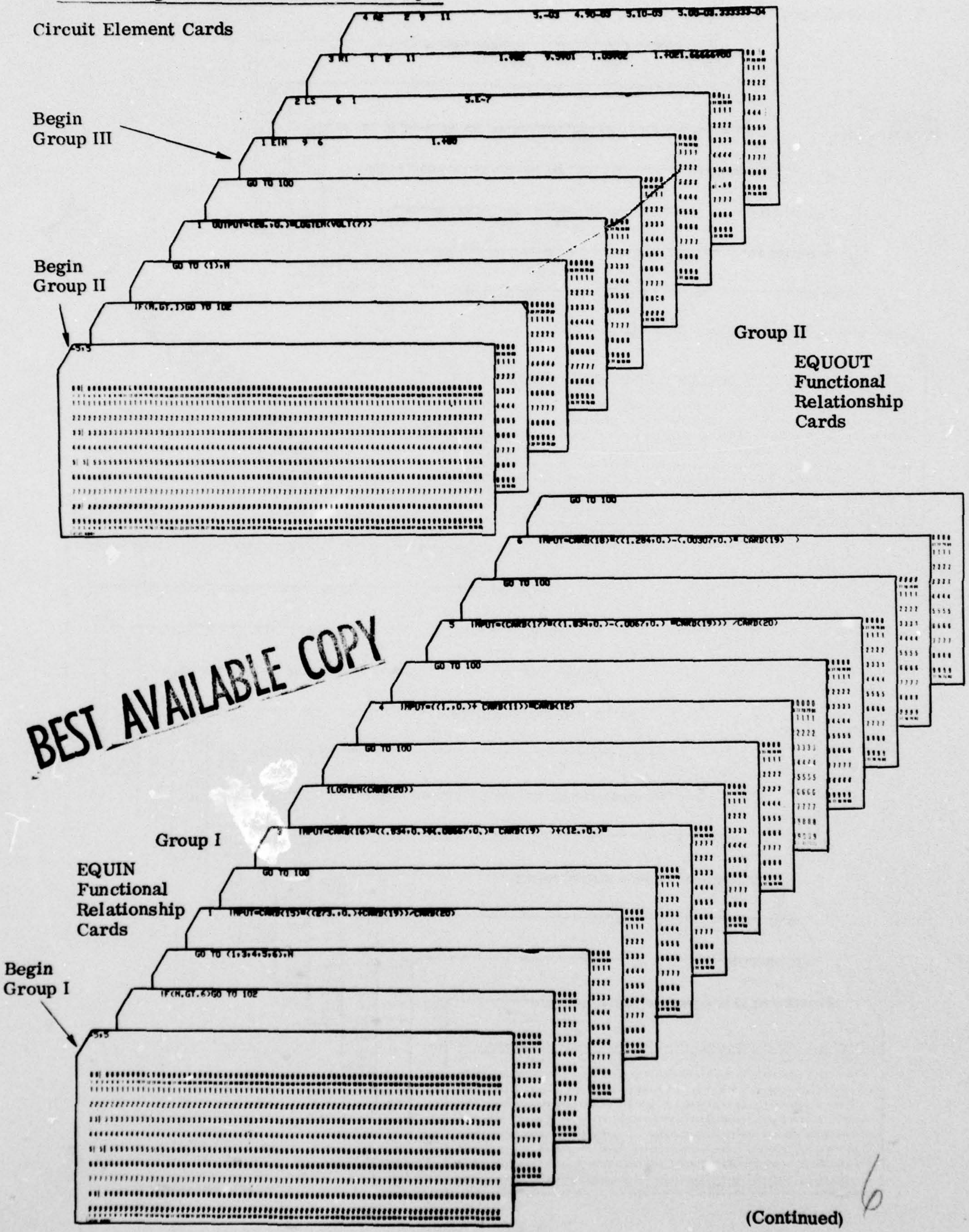
R_T = temperature in °C;

R_{IC} = collector current in mA.

---

*The quantity (0.99 to 1.01) accounts for measurement accuracy and the uncertainty of the constants defining R_{K1}.

E.4 Listing of Punched Cards for Example

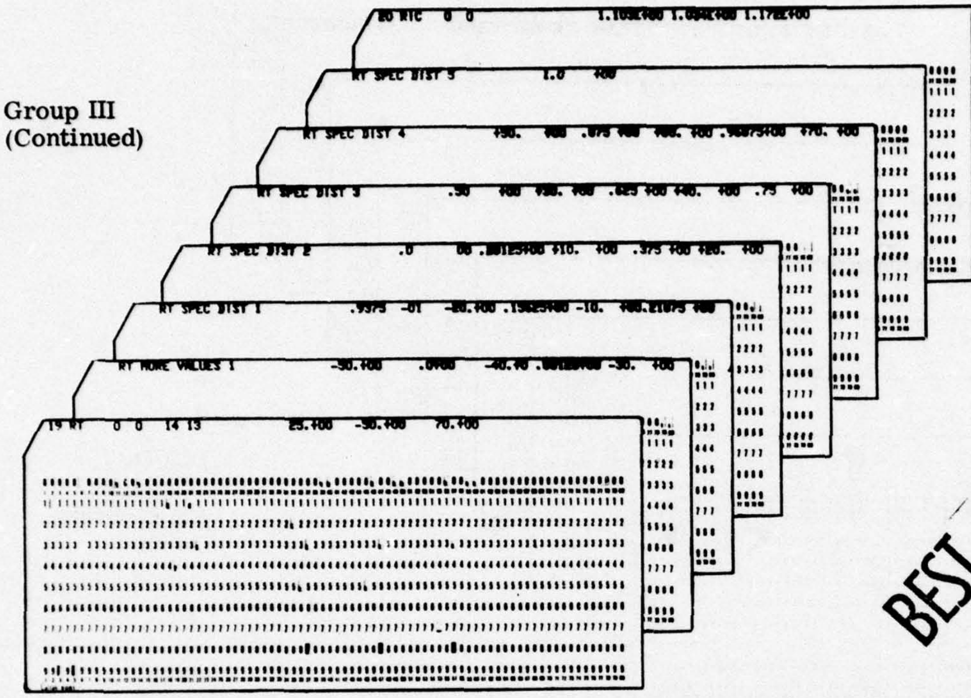


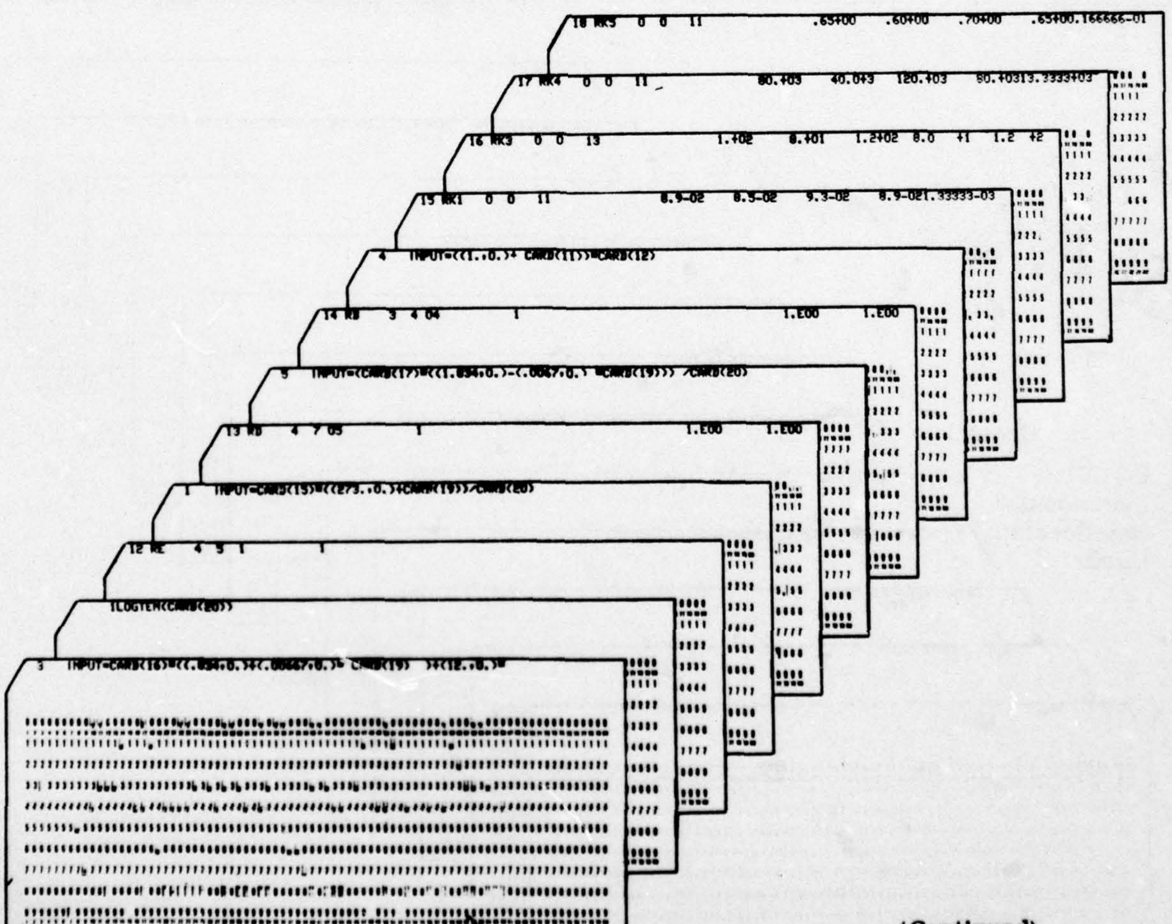
(Continued)

6

E.4 (Continued)

Group III
(Continued)

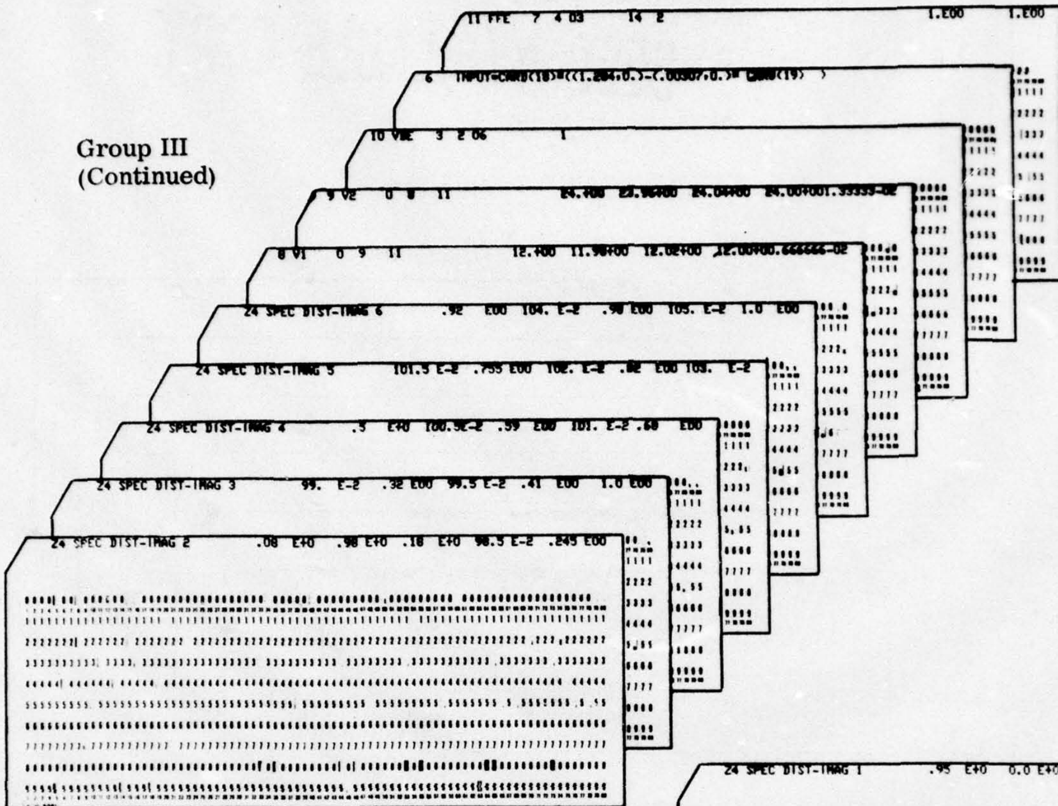


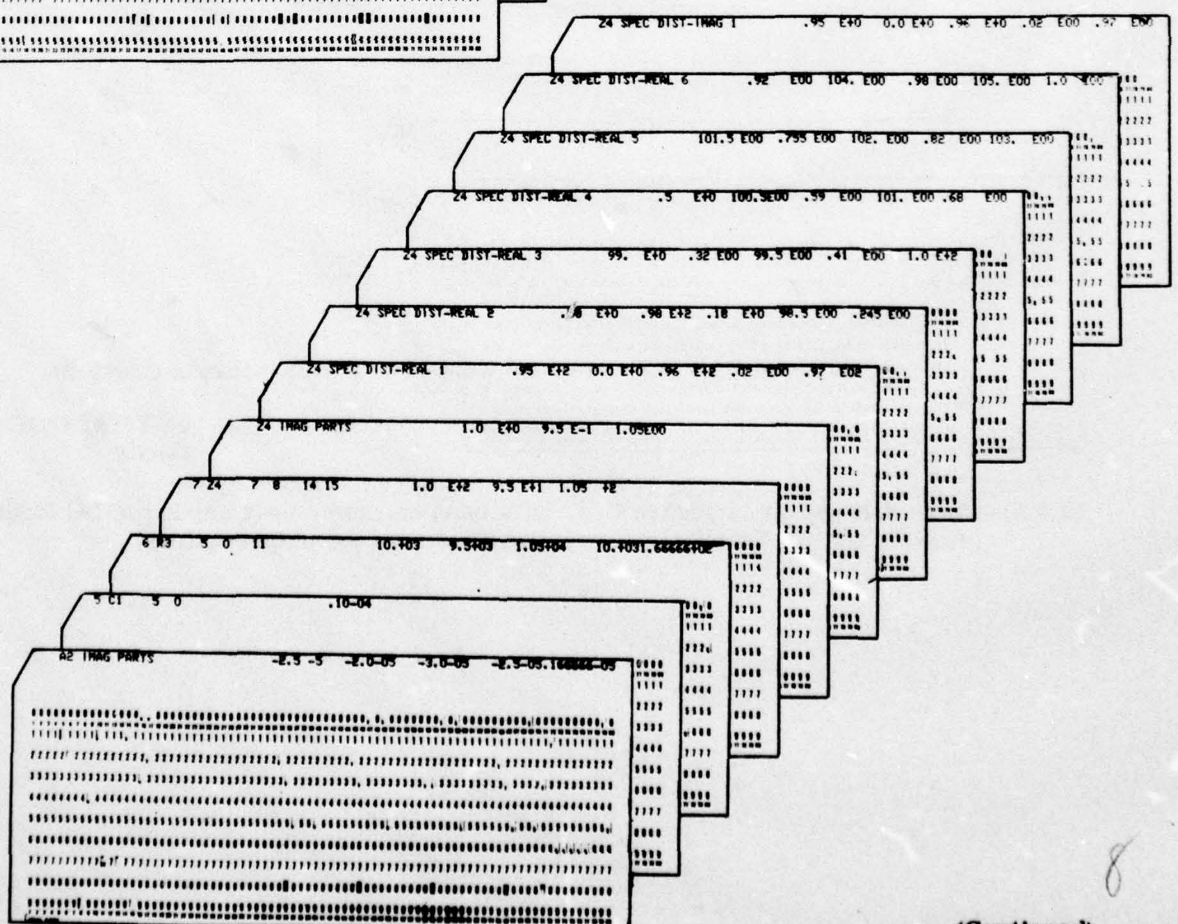


(Continued)

E.4 (Continued)

Group III
(Continued)

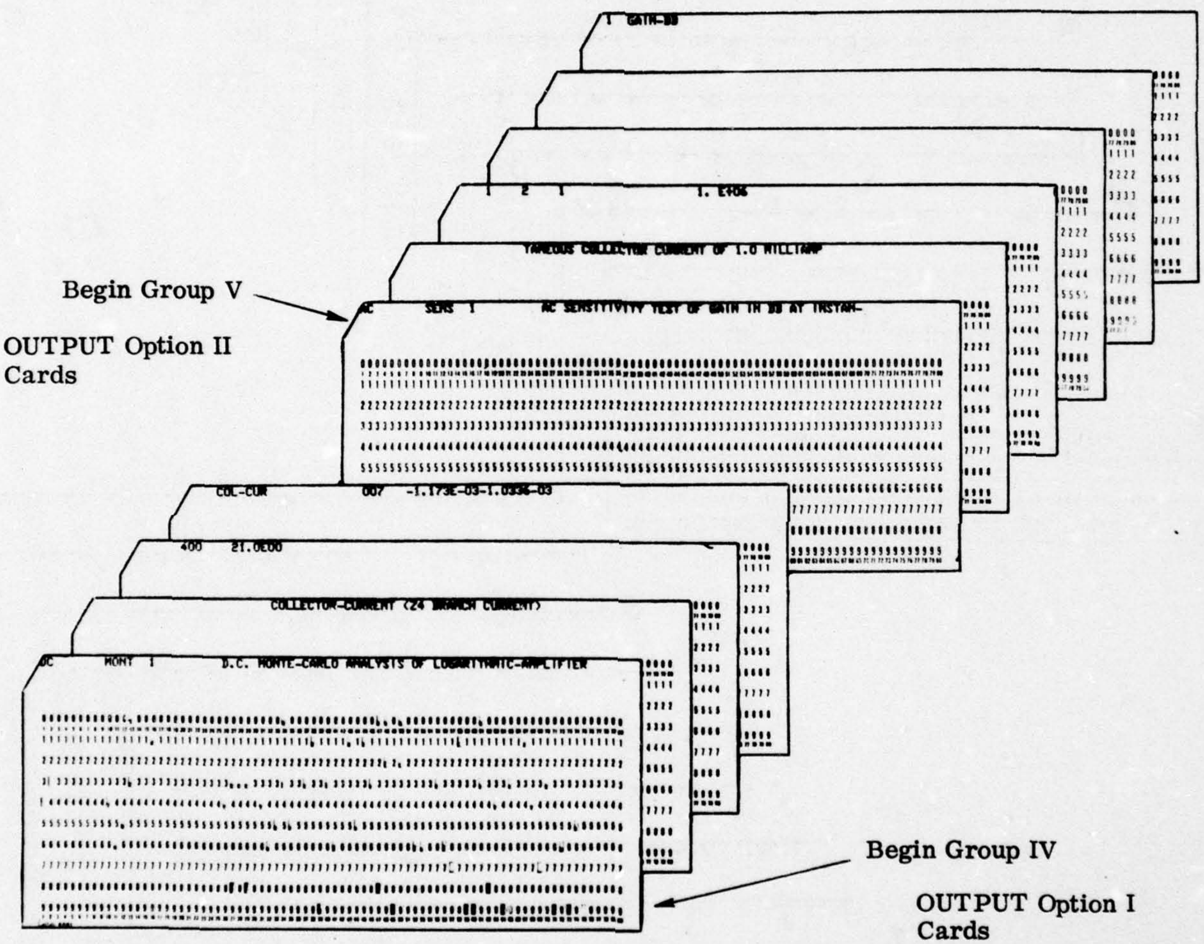




8

(Continued)

E.4 (Continued)



Begin Group V

OUTPUT Option II Cards

Begin Group IV

OUTPUT Option I Cards

NOTE: Cards that appear in Figure C-1, have been omitted. Only cards for DC Monte Carlo Analysis and AC Sensitivity Testing are included for output options.

E.5 Circuit Element Values and Equations

LISTING OF CIRCUIT ELEMENT CARDS

NO.	TYPE	NODES		SENS	MC DIST.	NOMINAL	LOW	HIGH	MC MEAN	MC ST.DEV.	REF.CIR.EL	SOURCE RES
1	EIN	9	6	NO		1.000+00	-0.000	-0.000	-0.000	-0.000		1.000+00
2	LS	6	1	NO		5.000-07	-0.000	-0.000	-0.000	-0.000		
3	R1	1	2	YES	NORMAL	1.000+02	9.500+01	1.050+02	1.000+02	1.667+00		
4	A2	2	9	YES	NORMAL	RE 5.000-03	4.900-03	5.100-03	5.000-03	3.333-05		
						IM-2.500-05	-2.000-05	-3.000-05	-2.500-05	1.667-06		
5	C1	5	0	NO		1.000-05	-0.000	-0.000	-0.000	-0.000		
6	R3	5	0	YES	NORMAL	1.000+04	9.500+03	1.050+04	1.000+04	1.667+02		
7	Z4	7	8	YES	SPECIAL	RE 1.000+02	9.500+01	1.050+02	-0.000	-0.000		
						IM 1.000+00	9.500-01	1.050+00	-0.000	-0.000		
8	V1	0	9	YES	NORMAL	1.200+01	1.198+01	1.202+01	1.200+01	6.667-03		1.000+00
9	V2	0	8	YES	NORMAL	2.400+01	2.396+01	2.404+01	2.400+01	1.333-02		1.000+00
10	VBE	3	2			-0.000	VALUE DETERMINED BY EQUATION 6					1.000+00
11	FFE	7	4			-0.000	VALUE DETERMINED BY EQUATION 3				14 RB	0.000
12	RE	4	5			-0.000	VALUE DETERMINED BY EQUATION 1					
13	RD	4	7			-0.000	VALUE DETERMINED BY EQUATION 5					
14	RB	3	4			-0.000	VALUE DETERMINED BY EQUATION 4					
15	RK1	0	0	YES	NORMAL	8.900-02	8.500-02	9.300-02	8.900-02	1.333-03		
16	RK3	0	0	YES	RECTANG	1.000+02	8.000+01	1.200+02	8.000+01	1.200+02		
17	RK4	0	0	YES	NORMAL	8.000+04	4.000+04	1.200+05	8.000+04	1.333+04		
18	RK5	0	0	YES	NORMAL	6.500-01	6.000-01	7.000-01	6.500-01	1.667-02		
19	RT	0	0	YES	SPECIAL	2.500+01	-5.000+01	7.000+01	-3.500+01	-2.000+01		
19	RT	ADDITIONAL VALUES				-5.000+00	1.000+01	2.500+01	4.000+01	5.500+01		
20	RIC	0	0	YES		1.103+00	1.034+00	1.172+00	-0.000	-0.000		

THE EQUATIONS BELOW ARE EQUIN RELATIONSHIPS DESCRIBING THE PARTICULAR CIRCUIT ELEMENTS ABOVE .

```
6   INPUT=CARD(18)*((1.284,0.)-(.00307,0.)* CARD(19)  )

3   INPUT=CARD(16)*((.834,0.)+(.00667,0.)* CARD(19)  )+(12.,0.)*
   1LOGTEN(CARD(20))

1   INPUT=CARD(15)*((273.,0.)+CARD(19))/CARD(20)

5   INPUT=(CARD(17)*((1.834,0.)-(.0067,0.) *CARD(19))) /CARD(20)

4   INPUT=((1.,0.)+ CARD(11))*CARD(12)
```

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E.6 Cumulative Distribution of R_T and Z_4

Z4 REQUIRES A SPECIAL SET OF DATA POINTS DESCRIBING THE DISTRIBUTION FOR MONTE CARLO ANALYSIS. THESE DATA POINTS ARE LISTED BELOW.

REAL VALUES	UNIFORMLY DISTRIBUTED RANDOM VARIABLES
9.50000000+01	0.00000000
9.60000000+01	2.00000000-02
9.70000000+01	7.99999990-02
9.80000000+01	1.80000000-01
9.85000000+01	2.45000000-01
9.89999990+01	3.19999990-01
9.95000000+01	4.10000000-01
1.00000000+02	5.00000000-01
1.00499999+02	5.90000000-01
1.00999999+02	6.80000000-01
1.01500000+02	7.55000000-01
1.01999999+02	8.19999990-01
1.02999998+02	9.19999990-01
1.03999999+02	9.80000000-01
1.04999999+02	1.00000000+00

IMAGINARY VALUES	UNIFORMLY DISTRIBUTED RANDOM VARIABLES
9.50000000-01	0.00000000
9.59999990-01	2.00000000-02
9.70000000-01	7.99999990-02
9.80000000-01	1.80000000-01
9.85000000-01	2.45000000-01
9.89999990-01	3.19999990-01
9.95000000-01	4.10000000-01
1.00000000+00	5.00000000-01
1.00499999+00	5.90000000-01
1.00999999+00	6.80000000-01
1.01499998+00	7.55000000-01
1.01999999+00	8.19999990-01
1.02999998+00	9.19999990-01
1.03999999+00	9.80000000-01
1.04999999+00	1.00000000+00

RT REQUIRES A SPECIAL SET OF DATA POINTS DESCRIBING THE DISTRIBUTION FOR MONTE CARLO ANALYSIS. THESE DATA POINTS ARE LISTED BELOW.

REAL VALUES	UNIFORMLY DISTRIBUTED RANDOM VARIABLES
-5.00000000+01	0.00000000
-4.00000000+01	3.12500000-02
-3.00000000+01	9.37500000-02
-2.00000000+01	1.56250000-01
-1.00000000+01	2.18750000-01
0.00000000	2.81250000-01
1.00000000+01	3.75000000-01
2.00000000+01	5.00000000-01
3.00000000+01	6.25000000-01
4.00000000+01	7.50000000-01
5.00000000+01	8.75000000-01
5.99999990+01	9.68750000-01
7.00000000+01	1.00000000+00

10

E.7 DC Sensitivity Test of Collector Current

```
DC ANALYSIS. SENS SOLUTION. TITLED    D.C. SENSITIVITY TEST OF LOGARITHMIC-AMPLIFIER
                                            COLLECTOR-CURRENT (Z4 BRANCH CURRENT)

THE SENSITIVITY TEST IS A SERIES OF COMPUTATIONS WHERE EACH INPUT PARAMETER IS INDIVIDUALLY SET TO ITS HIGHEST AND LOWEST VALUE
AND THE MAGNITUDE / PHASE OF CURRENT  IS COMPUTED AT EACH VALUE. THESE DATA ARE TABULATED IN COLUMNS TWO AND THREE.  A NEGATIVE
SIGN. IN COLUMN FOUR INDICATES THAT AN INCREASE IN THE VALUE OF A PARTICULAR INPUT PARAMETER CAUSES A DECREASE IN CURRENT .
INPUT PARAMETERS ARE LISTED ACCORDING TO THEIR DESCENDING ORDER OF AFFECT ON CURRENT
THE LAST ROW OF THE TABULATION INDICATES WORST CASE VALUES FOR CURRENT  WHEN ALL INPUT PARAMETERS ARE COLLECTIVELY SET TO THEIR
HIGHEST OR LOWEST VALUES.

                TABULATED RESULTS OF A SENSITIVITY TEST FOR THE MAGNITUDE/PHASE OF CURRENT
                THE NOMINAL VALUE OF CURRENT  IS  -1.106260-03   0.000000    DEGREES

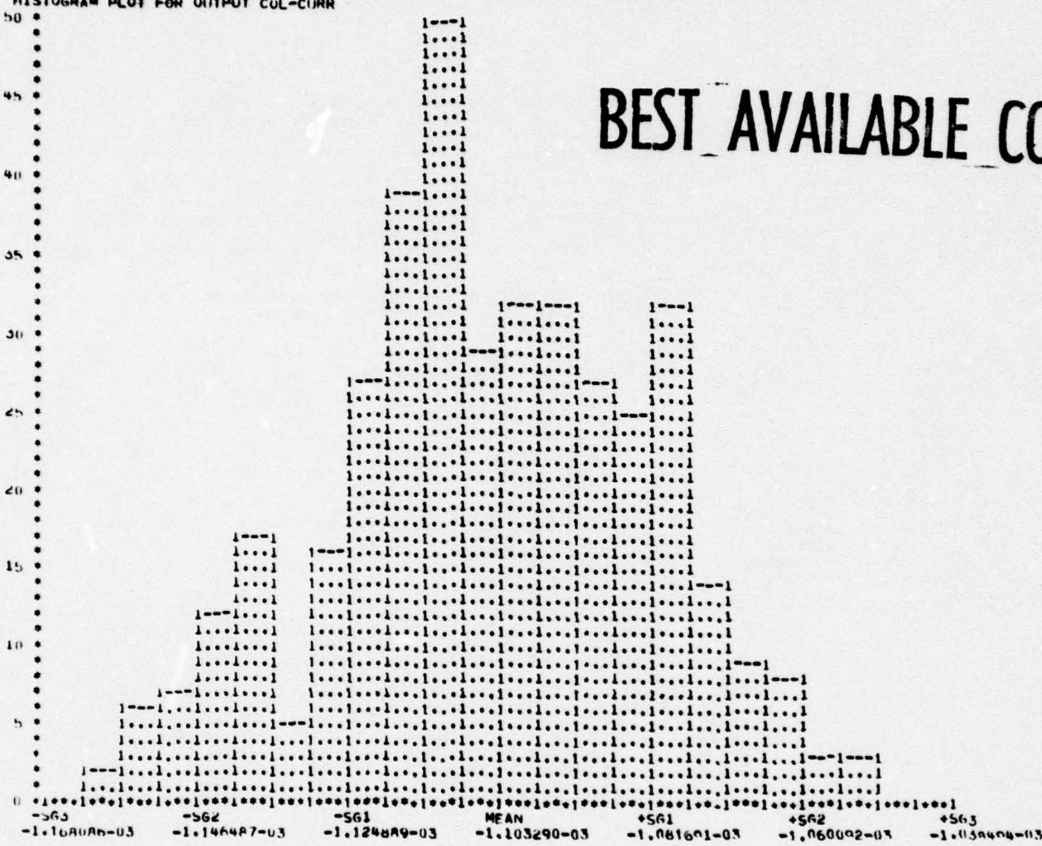
                OUTPUT IS CURRENT THROUGH THE COMPONENT Z4

MAGNITUDE OF OUTPUT
```

INPUT PARAMETER	MINIMUM CURRENT	MAXIMUM CURRENT	MAXIMUM(CURRENT)-MINIMUM(CURRENT) NOMINAL(CURRENT)
Z4	-1.000902-03	-1.106260-03	1.000002-01
R3	-1.053870-03	-1.164134-03	-9.966530-02
RT	-1.082547-03	-1.116908-03	3.106041-02
RR5	-1.100316-03	-1.112201-03	-1.074355-02
RR3	-1.103768-03	-1.107931-03	3.762944-03
V1	-1.104290-03	-1.108227-03	3.558199-03
RR4	-1.105824-03	-1.107562-03	-1.571119-03
RR1	-1.106031-03	-1.106486-03	-4.116330-04
V2	-1.106255-03	-1.106262-03	6.471845-06
A2	-1.106255-03	-1.106262-03	6.471845-06
WORST CASE	-1.017287-03	-1.185740-03	

E. 8 DC Monte Carlo Analysis of Collector Current

```
DC ANALYSIS, MONTSOLUTION TITLED      D.C. MONTE-CARLO ANALYSIS OF LOGARITHMIC-AMPLIFIER
                                           COLLECTOR-CURRENT (Z4 BRANCH CURRENT)
NUMBER OF SAMPLES= 400, STARTING VALUE FOR  RANDOM NUMBER GENERATOR= 21.00000
HISTOGRAM PLOT FOR OUTPUT COL-CURR
```



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```
SUMMARY INFORMATION ON OUTPUT COL-CURR FOR PRECEEDING HISTOGRAM.

MEDIAN LIES BETWEEN   -1.1046940-03 AND   -1.1033000-03

MEAN IS   -1.1032899-03

VARIANCE IS    4.6650647-10

STANDARD DEVIATION IS    2.1598761-05

SUMMARY OF OUT OF BOUNDS POINTS WHICH DIDNT  APPEAR ON THE HISTOGRAM.

NUMBER ABOVE UPPER BOUND (-1.033600-03)=   0

NUMBER BELOW LOWER BOUND (-1.173000-03)=   3

NUMBER BETWEEN 3 SIGMA POINT (-1.038494-03) AND UPPER BOUND=   1

NUMBER BELOW 3 SIGMA POINT (-1.168086-03) AND LOWER BOUND=   1

-SG3
      INTERVAL FROM -1.168086-03 TO -1.162687-03 =  0
      INTERVAL FROM -1.162687-03 TO -1.157287-03 =  2
      INTERVAL FROM -1.157287-03 TO -1.151887-03 =  6
      INTERVAL FROM -1.151887-03 TO -1.146488-03 =  7

-SG2
      INTERVAL FROM -1.146488-03 TO -1.141088-03 = 12
      INTERVAL FROM -1.141088-03 TO -1.135688-03 = 17
      INTERVAL FROM -1.135688-03 TO -1.130288-03 =  5
      INTERVAL FROM -1.130288-03 TO -1.124889-03 = 16

-SG1
      INTERVAL FROM -1.124889-03 TO -1.119489-03 = 27
      INTERVAL FROM -1.119489-03 TO -1.114089-03 = 39
      INTERVAL FROM -1.114089-03 TO -1.108690-03 = 50
      INTERVAL FROM -1.108690-03 TO -1.103290-03 = 29

MEAN
      INTERVAL FROM -1.103290-03 TO -1.097890-03 = 32
      INTERVAL FROM -1.097890-03 TO -1.092491-03 = 32
      INTERVAL FROM -1.092491-03 TO -1.087091-03 = 27
      INTERVAL FROM -1.087091-03 TO -1.081691-03 = 25

+SG1
      INTERVAL FROM -1.081691-03 TO -1.076292-03 = 32
      INTERVAL FROM -1.076292-03 TO -1.070892-03 = 14
      INTERVAL FROM -1.070892-03 TO -1.065492-03 =  9
      INTERVAL FROM -1.065492-03 TO -1.060093-03 =  8

+SG2
      INTERVAL FROM -1.060093-03 TO -1.054693-03 =  3
      INTERVAL FROM -1.054693-03 TO -1.049293-03 =  3
      INTERVAL FROM -1.049293-03 TO -1.043894-03 =  0
      INTERVAL FROM -1.043894-03 TO -1.038494-03 =  0

+SG3
```


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E.9 AC Sensitivity Test of Gain

AC ANALYSIS, SENS SOLUTION, TITLED AC SENSITIVITY TEST OF GAIN IN DB AT INSTAN-
TANEOUS COLLECTOR CURRENT OF 1. MILLIAMP

FREQUENCY=1 .100000+07

THE SENSITIVITY TEST IS A SERIES OF COMPUTATIONS WHERE EACH INPUT PARAMETER IS INDIVIDUALLY SET TO ITS HIGHEST AND LOWEST VALUE AND THE MAGNITUDE / PHASE OF GAIN-DB IS COMPUTED AT EACH VALUE. THESE DATA ARE TABULATED IN COLUMNS TWO AND THREE. A NEGATIVE SIGN IN COLUMN FOUR INDICATES THAT AN INCREASE IN THE VALUE OF A PARTICULAR INPUT PARAMETER CAUSES A DECREASE IN GAIN-DB .
INPUT PARAMETERS ARE LISTED ACCORDING TO THEIR DESCENDING ORDER OF AFFECT ON GAIN-DB
THE LAST ROW OF THE TABULATION INDICATES WORST CASE VALUES FOR GAIN-DB WHEN ALL INPUT PARAMETERS ARE COLLECTIVELY SET TO THEIR HIGHEST OR LOWEST VALUES.

TABULATED RESULTS OF A SENSITIVITY TEST FOR THE MAGNITUDE/PHASE OF GAIN-DB
THE NOMINAL VALUE OF GAIN-DB IS 2.599271+00 0.000000 DEGREES

MAGNITUDE OF OUTPUT

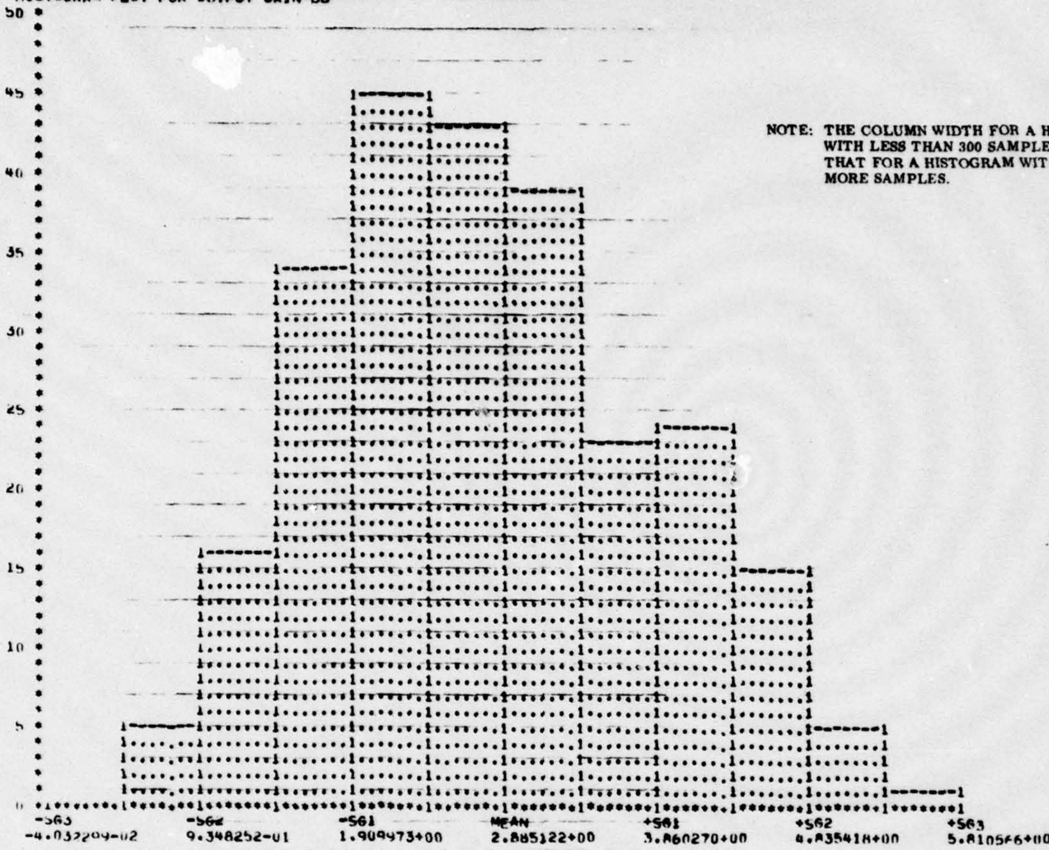
INPUT PARAMETER	MINIMUM GAIN-DB	MAXIMUM GAIN-DB	MAXIMUM(GAIN-DB)-MINIMUM(GAIN-DB) / NOMINAL(GAIN-DB)
RT	1.435214+00	4.844200+00	-1.311516+00
RIC	2.045022+00	3.119472+00	4.133658-01
Z4	2.153873+00	3.022927+00	3.343452-01
RE1	2.222538+00	2.993095+00	-2.964511-01
R1	2.452465+00	2.748601+00	-1.139306-01
A2	2.542041+00	2.656882+00	-4.418183-02
RK3	2.549093+00	2.632489+00	3.227686-02
RE4	2.594609+00	2.600892+00	2.417187-03
RK5	2.599175+00	2.599369+00	7.479041-05
R3	2.599175+00	2.599369+00	7.479041-05
WORST CASE	-1.897897-01	6.455984+00	

E. 10 AC Monte Carlo Analysis of Gain

AC ANALYSIS, MONTSOLUTION TITLED AC MONTE CARLO ANALYSIS OF GAIN IN DB AT
INSTANTANEOUS COLLECTOR CURRENT OF 1. MILLIAMP.

NUMBER OF SAMPLES= 250, STARTING VALUE FOR RANDOM NUMBER GENERATOR= 21.00000

HISTOGRAM PLOT FOR OUTPUT GAIN-DB



NOTE: THE COLUMN WIDTH FOR A HISTOGRAM WITH LESS THAN 300 SAMPLES IS TWICE THAT FOR A HISTOGRAM WITH 300 OR MORE SAMPLES.

SUMMARY INFORMATION ON OUTPUT GAIN-DB FOR PRECEEDING HISTOGRAM.

MEDIAN LIES BETWEEN 2.7869999+00 AND 2.8500000+00

MEAN IS 2.8851216+00

VARIANCE IS 9.5091400-01

STANDARD DEVIATION IS 9.7514819-01

SUMMARY OF OUT OF BOUNDS POINTS WHICH DIDNT APPEAR ON THE HISTOGRAM.

NUMBER ABOVE UPPER BOUND (6.000000+00)= 0

NUMBER BELOW LOWER BOUND (-3.000000-01)= 0

NUMBER BETWEEN 3 SIGMA POINT (5.810566+00) AND UPPER BOUND= 0

NUMBER BELOW 3 SIGMA POINT (-4.032299-02) AND LOWER BOUND= 0

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```
-SG3
     INTERVAL FROM -4.032299-02 TO  4.472511-01 =  0
     INTERVAL FROM  4.472511-01 TO  9.348252-01 =  5
-SG2
     INTERVAL FROM  9.348252-01 TO  1.422399+00 = 16
     INTERVAL FROM  1.422399+00 TO  1.909973+00 = 34
-SG1
     INTERVAL FROM  1.909973+00 TO  2.397547+00 = 45
     INTERVAL FROM  2.397547+00 TO  2.885121+00 = 43
MEAN
     INTERVAL FROM  2.885121+00 TO  3.372696+00 = 39
     INTERVAL FROM  3.372696+00 TO  3.860270+00 = 23
+SG1
     INTERVAL FROM  3.860270+00 TO  4.347844+00 = 28
     INTERVAL FROM  4.347844+00 TO  4.835418+00 = 15
+SG2
     INTERVAL FROM  4.835418+00 TO  5.322992+00 =  5
     INTERVAL FROM  5.322992+00 TO  5.810566+00 =  1
+SG3
```

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E.11a Special Solutions of Gain Versus Temperature

AC ANALYSIS, SPCL SOLUTION, TITLED GAIN IN DB VERSUS TEMPERATURE

COMPONENT VALUES FOR SPECIAL SOLUTIONS

NO.	TYPE	REAL PART	IMAGINARY PART
1	EIN	-1.0000+00	0.0000
2	LS	0.0000	3.1416+00
3	R1	1.0000+02	0.0000
4	A2	1.9999+02	9.9998-01
5	C1	0.0000	-1.5915-02
6	R3	1.0000+04	0.0000
7	Z4	1.0000+02	1.0000+00
11	HFE	5.0961+01	0.0000
12	RF	1.7994+01	0.0000
13	RD	1.5732+05	-0.0000
14	RB	9.2777+02	0.0000
15	RK1	8.9000-02	0.0000
16	RK3	1.0000+02	0.0000
17	RK4	8.0000+04	0.0000
18	RK5	6.5000-01	0.0000
19	RT	-5.0000+01	0.0000
20	RIC	1.1030+00	0.0000

AC ANALYSIS, SPCL SOLUTION, TITLED GAIN IN DB VERSUS TEMPERATURE

FREQUENCY= 1.000000+06 HZ

COMPUTED OUTPUT FROM SPECIAL EQUATIONS

NAME	POLAR COORDINATES, PHASE	MAGNITUDE	RECTANGULAR COORDINATES REAL	IMAG
GAIN-DB	.000	4.8442945+00	4.8442945+00	0.0000000

E.11b Special Solutions of Gain Versus Temperature

AC ANALYSIS, SPCL SOLUTION, TITLED GAIN IN DB VERSUS TEMPERATURE

COMPONENT VALUES FOR SPECIAL SOLUTIONS

NO.	TYPE	REAL PART	IMAGINARY PART
1	EIN	-1.0000+00	0.0000
2	LS	0.0000	3.1416+00
3	R1	1.0000+02	0.0000
4	A2	1.9999+02	9.9998-01
5	C1	0.0000	-1.5915-02
6	R3	1.0000+04	0.0000
7	Z4	1.0000+02	1.0000+00
11	HFE	6.0566+01	0.0000
12	RF	1.9204+01	0.0000
13	RD	1.5003+05	-0.0000
14	RB	1.1823+03	0.0000
15	RK1	8.9000-02	0.0000
16	RK3	1.0000+02	0.0000
17	RK4	8.0000+04	0.0000
18	RK5	6.5000-01	0.0000
19	RT	-3.5000+01	0.0000
20	RIC	1.1030+00	0.0000

AC ANALYSIS, SPCL SOLUTION, TITLED GAIN IN DB VERSUS TEMPERATURE

FREQUENCY= 1.000000+06 HZ

COMPUTED OUTPUT FROM SPECIAL EQUATIONS

NAME	POLAR COORDINATES, PHASE	MAGNITUDE	RECTANGULAR COORDINATES REAL	IMAG
GAIN-DB	.000	4.3720943+00	4.3720943+00	0.0000000

E. 11c Special Solutions of Gain Versus Temperature

AC ANALYSIS, SPCL SOLUTION, TITLED GAIN IN DB VERSUS TEMPERATURE

COMPONENT VALUES FOR SPECIAL SOLUTIONS

NO.	TYPE	REAL PART	IMAGINARY PART
1	EIN	-1.0000+00	0.0000
2	LS	0.0000	3.1416+00
3	R1	1.0000+02	0.0000
4	A2	1.9999+02	9.9998-01
5	C1	0.0000	-1.5915-02
6	R3	1.0000+04	0.0000
7	Z4	1.0000+02	1.0000+00
11	FFE	7.0571+01	0.0000
12	RF	2.0414+01	0.0000
13	RD	1.4274+05	-0.0000
14	RB	1.4611+03	0.0000
15	RK1	8.9000-02	0.0000
16	RK3	1.0000+02	0.0000
17	RK4	8.0000+04	0.0000
18	RK5	6.5000-01	0.0000
19	RT	-2.0000+01	0.0000
20	RIC	1.1030+00	0.0000

AC ANALYSIS, SPCL SOLUTION, TITLED GAIN IN DB VERSUS TEMPERATURE

FREQUENCY= 1.000000+06 HZ

COMPUTED OUTPUT FROM SPECIAL EQUATIONS

NAME	POLARCOORDINATES, PHASE	MAGNITUDE	RECTANGULAR COORDINATES REAL	IMAG
GAIN-DB	.000	3.9069209+00	3.9069209+00	0.0000000

E. 11d Special Solutions of Gain Versus Temperature

AC ANALYSIS, SPCL SOLUTION, TITLED GAIN IN DB VERSUS TEMPERATURE

COMPONENT VALUES FOR SPECIAL SOLUTIONS

NO.	TYPE	REAL PART	IMAGINARY PART
1	EIN	-1.0000+00	0.0000
2	LS	0.0000	3.1416+00
3	R1	1.0000+02	0.0000
4	A2	1.9999+02	9.9998-01
5	C1	0.0000	-1.5915-02
6	R3	1.0000+04	0.0000
7	Z4	1.0000+02	1.0000+00
11	FFE	8.0576+01	0.0000
12	RF	2.1629+01	0.0000
13	RD	1.3545+05	-0.0000
14	RB	1.7641+03	0.0000
15	RK1	8.9000-02	0.0000
16	RK3	1.0000+02	0.0000
17	RK4	8.0000+04	0.0000
18	RK5	6.5000-01	0.0000
19	RT	-5.0000+00	0.0000
20	RIC	1.1030+00	0.0000

AC ANALYSIS, SPCL SOLUTION, TITLED GAIN IN DB VERSUS TEMPERATURE

FREQUENCY= 1.000000+06 HZ

COMPUTED OUTPUT FROM SPECIAL EQUATIONS

NAME	POLARCOORDINATES, PHASE	MAGNITUDE	RECTANGULAR COORDINATES REAL	IMAG
GAIN-DB	.000	3.4550604+00	3.4550604+00	0.0000000

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E.11e Special Solutions of Gain Versus Temperature

AC ANALYSIS, SPCL SOLUTION, TITLED GAIN IN DB VERSUS TEMPERATURE

COMPONENT VALUES FOR SPECIAL SOLUTIONS

NO.	TYPE	REAL PART	IMAGINARY PART
1	EIN	-1.0000+00	0.0000
2	LS	0.0000	3.1416+00
3	R1	1.0000+02	0.0000
4	R2	1.9999+02	9.9998-01
5	C1	0.0000	-1.5915-02
6	R3	1.0000+04	0.0000
7	Z4	1.0000+02	1.0000+00
11	FFE	9.0581+01	0.0000
12	RF	2.2835+01	0.0000
13	RD	1.2816+05	-0.0000
14	RB	2.0912+03	0.0000
15	RK1	8.9000-02	0.0000
16	RK3	1.0000+02	0.0000
17	RK4	8.0000+04	0.0000
18	RK5	6.5000-01	0.0000
19	RT	1.0006+01	0.0000
20	RTC	1.1030+00	0.0000

AC ANALYSIS, SPCL SOLUTION, TITLED GAIN IN DB VERSUS TEMPERATURE

FREQUENCY= 1.000000+06 HZ

COMPUTED OUTPUT FROM SPECIAL EQUATIONS

NAME	POLARCOORDINATES, PHASE	MAGNITUDE	RECTANGULAR COORDINATES REAL	IMAG
GAIN-DB	.000	3.0189548+00	3.0189548+00	0.0000000

E.11f Special Solutions of Gain Versus Temperature

AC ANALYSIS, SPCL SOLUTION, TITLED GAIN IN DB VERSUS TEMPERATURE

COMPONENT VALUES FOR SPECIAL SOLUTIONS

NO.	TYPE	REAL PART	IMAGINARY PART
1	EIN	-1.0000+00	0.0000
2	LS	0.0000	3.1416+00
3	R1	1.0000+02	0.0000
4	R2	1.9999+02	9.9998-01
5	C1	0.0000	-1.5915-02
6	R3	1.0000+04	0.0000
7	Z4	1.0000+02	1.0000+00
11	FFE	1.0058+02	0.0000
12	RF	2.4045+01	0.0000
13	RD	1.2087+05	-0.0000
14	RB	2.4427+03	0.0000
15	RK1	8.9000-02	0.0000
16	RK3	1.0000+02	0.0000
17	RK4	8.0000+04	0.0000
18	RK5	6.5000-01	0.0000
19	RT	2.5000+01	0.0000
20	RTC	1.1030+00	0.0000

AC ANALYSIS, SPCL SOLUTION, TITLED GAIN IN DB VERSUS TEMPERATURE

FREQUENCY= 1.000000+06 HZ

COMPUTED OUTPUT FROM SPECIAL EQUATIONS

NAME	POLARCOORDINATES, PHASE	MAGNITUDE	RECTANGULAR COORDINATES REAL	IMAG
GAIN-DB	.000	2.5992711+00	2.5992711+00	0.0000000

E.11g Special Solutions of Gain Versus Temperature

AC ANALYSIS, SPCL SOLUTION, TITLED GAIN IN DB VERSUS TEMPERATURE

COMPONENT VALUES FOR SPECIAL SOLUTIONS

NO.	TYPE	REAL PART	IMAGINARY PART
1	EIN	-1.0000+00	0.0000
2	LS	0.0000	3.1416+00
3	R1	1.0000+02	0.0000
4	R2	1.9999+02	9.9998-01
5	C1	0.0000	-1.5915-02
6	R3	1.0000+04	0.0000
7	Z4	1.0000+02	1.0000+00
11	FFE	1.1059+02	0.0000
12	RF	2.5256+01	0.0000
13	RD	1.1358+05	-0.0000
14	RB	2.8183+03	0.0000
15	RK1	8.9000-02	0.0000
16	RK3	1.0000+02	0.0000
17	RK4	8.0000+04	0.0000
18	RK5	6.5000-01	0.0000
19	RT	4.0000+01	0.0000
20	RIC	1.1030+00	0.0000

AC ANALYSIS, SPCL SOLUTION, TITLED GAIN IN DB VERSUS TEMPERATURE

FREQUENCY= 1.000000+06 HZ

COMPUTED OUTPUT FROM SPECIAL EQUATIONS

NAME	POLARCOORDINATES, PHASE	MAGNITUDE	RECTANGULAR COORDINATES REAL	IMAG
GAIN-DB	.000	2.1958274+00	2.1958274+00	0.0000000

E.11h Special Solutions of Gain Versus Temperature

AC ANALYSIS, SPCL SOLUTION, TITLED GAIN IN DB VERSUS TEMPERATURE

COMPONENT VALUES FOR SPECIAL SOLUTIONS

NO.	TYPE	REAL PART	IMAGINARY PART
1	EIN	-1.0000+00	0.0000
2	LS	0.0000	3.1416+00
3	R1	1.0000+02	0.0000
4	R2	1.9999+02	9.9998-01
5	C1	0.0000	-1.5915-02
6	R3	1.0000+04	0.0000
7	Z4	1.0000+02	1.0000+00
11	FFE	1.2060+02	0.0000
12	RF	2.6466+01	0.0000
13	RD	1.0629+05	-0.0000
14	RB	3.2182+03	0.0000
15	RK1	8.9000-02	0.0000
16	RK3	1.0000+02	0.0000
17	RK4	8.0000+04	0.0000
18	RK5	6.5000-01	0.0000
19	RT	5.5000+01	0.0000
20	RIC	1.1030+00	0.0000

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AC ANALYSIS, SPCL SOLUTION, TITLED GAIN IN DB VERSUS TEMPERATURE

FREQUENCY= 1.000000+06 HZ

COMPUTED OUTPUT FROM SPECIAL EQUATIONS

NAME	POLARCOORDINATES, PHASE	MAGNITUDE	RECTANGULAR COORDINATES REAL	IMAG
GAIN-DB	.000	1.8080336+00	1.8080336+00	0.0000000

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E.11i Special Solutions of Gain Versus Temperature

```
          AC ANALYSIS, SPCL SOLUTION, TITLED      GAIN IN DB VERSUS TEMPERATURE
                    COMPONENT VALUES FOR SPECIAL SOLUTIONS


NO. TYPE  REAL PART  IMAGINARY PART

 1  EIN   -1.0000+00   0.0000
 2  LS     0.0000      6.1416+00
 3  R1     1.0000+02   0.0000
 4  R2     1.9999+02   9.9998-01
 5  C1     0.0000     -1.5915-02
 6  R3     1.0000+04   0.0000
 7  Z4     1.0000+02   1.0000+00
11  FFE    1.3060+02   0.0000
12  RF     2.7676+01   0.0000
13  RD     9.9005+04  -0.0000
14  RR     3.6422+03   0.0000
15  RK1    8.9000-02   0.0000
16  RK3    1.0000+02   0.0000
17  RK4    8.0000+04   0.0000
18  RK5    6.5000-01   0.0000
19  RT     7.0000+01   0.0000
20  RTC    1.1030+00   0.0000

          AC ANALYSIS, SPCL SOLUTION, TITLED      GAIN IN DB VERSUS TEMPERATURE

     FREQUENCY=    1.000000+06  HZ

COMPUTED OUTPUT FROM SPECIAL EQUATIONS

             POLARCOORDINATES,                                   RECTANGULAR COORDINATES
NAME         PHASE      MAGNITUDE                             REAL          IMAG

GAIN-DB       .000      1.4351157+00                          1.4351157+00  0.0000000
```

E.12 Frequency Plot of Gain

(In preparation)

APPENDIX F

EXAMPLE OF NONLINEAR ANALYSIS

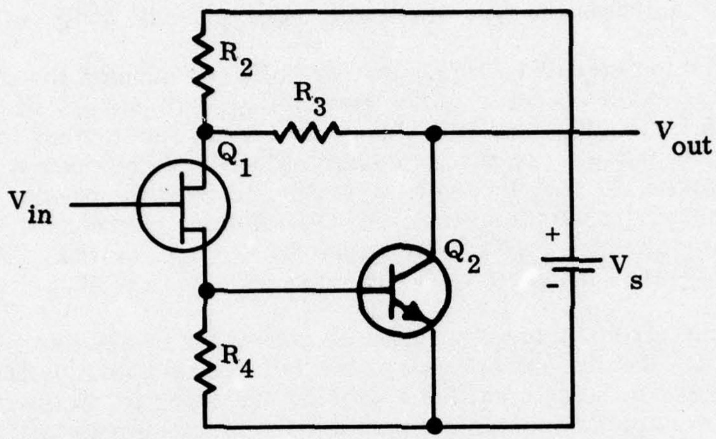
EXAMPLE OF NONLINEAR ANALYSIS

This example illustrates the use of the voltage-dependent circuit element option of SNAP II, and indicates the type of circuitry that must be analyzed in this manner.

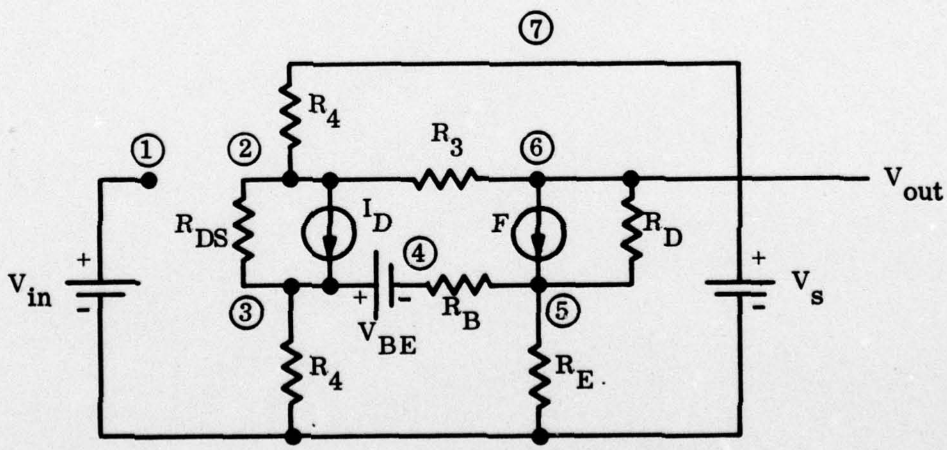
The illustrated circuit is a FET source-follower coupled through a common-emitter amplifier. The object is to determine V_{out} versus V_{in}. Since loop currents (and thus values for F, R_B, and R_E) change in a nonlinear manner with V_{in}, it might seem necessary to write more than one expression involving node voltages and circuit elements. However, to restrict the analysis to one dependent node voltage (for the purpose of conserving computer time), the Q_2 collector current for various values of V_{in} is computed manually with fixed values for F, R_B, and R_E. The new values of F, R_B, and R_E are then used for a subsequent analysis of V_{out} versus V_{in}.

Under some circumstances it might be necessary to make two or three iterations of this sort. If more iterations are involved, it is doubtless less expensive for the computer to make the computations rather than trying to confine the analysis to one dependent node voltage by supplementing the computer computations with manual computations.

F.1 **Actual Circuit**



F.2 **Equivalent Circuit**



where: $$I_D = I_{DSS}\left[1 - \frac{V_{in} - V_2}{V_p}\right]^2$$

F.3 Listing of Punched Cards for Example

```
5,5
    IF(N.GT.12)GO TO 102
    GO TO (12),N
12  INPUT=CARD(1)*((1.,0.)-(CARD(2)-VOLT(2))/CARD(3))**2
    GO TO 100
```

```
R2    2  7                                  4.E+03
R3    2  6                                8.E+02
R4    3  0                              2.E+03
VBE   4  3                             .65E00
1 RIBSS 0  0                         5.E-03
2 RVIN  0  0      1                 5.E00
RVIN MORE VALUES 1              5.0E00    7.E00    9.E00
3 RVP   0  0                       2.F+00
4 RB    4  5      1             116.F+00
RB MORE VALUES 1             860.0E00  1170.E00  1550.E00
RD    5  6                     1.E+05
RE    5  0        1          13.E+00
RE MORE VALUES 1           15.0E00    21.E00    30.E00
F     6  5        1    4   57.E+00
F MORE VALUES 1          56.0E00    54.E00    50.E00
RDS   3  2                1.E+06
D(ID) 2  3 12        1    .00125+00
12  INPUT=CARD(1)*((1.,0.)-(CARD(2)-VOLT(2))/CARD(3))**2
VS    0  7                12.E00
DC    1 SPCL    1          FIRST  SPECIAL SOLUTION RVIN= 5
      2                    3.5E00    3.0E0    5.0E0    2.0E-2
ALL
5 5      55
DC    1 SPCL    1          SECOND  SPECIAL SOLUTION RVIN= 7
      2                    5.3E00    5.0E0    7.0E0    2.0E-2
ALL
6 6      66
DC    1 SPCL    1          THIRD  SPECIAL SOLUTION RVIN= 9
      2                    7.2E00    7.0E0    9.0E0    2.0E-2
ALL
7 7      77
```

NOTE: Cards which appear in Appendix C Figure 1 and all other blank cards have been omitted.

F.4 Circuit Element Values and Equations

LISTING OF CIRCUIT ELEMENT CARDS

NO.	TYPE	NODES	SENS	MC DIST.	NOMINAL	LOW	HIGH	MC MEAN	MC ST.DEV.	REF.CIR.EL	SOURCE RFS
1	RIDSS	0 0	NO		5.000-03	-0.000	-0.000	-0.000	-0.000		
2	RVIN	0 0	NO		5.000+00	-0.000	-0.000	-0.000	-0.000		
2	RVIN	ADDITIONAL	VALUES		5.000+00	7.000+00	9.000+00	-0.000	-0.000		
3	RVP	0 0	NO		2.000+00	-0.000	-0.000	-0.000	-0.000		
4	RB	4 5	NO		1.160+02	-0.000	-0.000	-0.000	-0.000		
4	RB	ADDITIONAL	VALUES		8.600+02	1.170+03	1.550+03	-0.000	-0.000		
5	R2	2 7	NO		4.000+03	-0.000	-0.000	-0.000	-0.000		
6	R3	2 6	NO		8.000+02	-0.000	-0.000	-0.000	-0.000		
7	R4	3 0	NO		2.000+03	-0.000	-0.000	-0.000	-0.000		
8	VBE	4 3	NO		6.500-01	-0.000	-0.000	-0.000	-0.000		1.000+00
9	RD	5 6	NO		1.000+05	-0.000	-0.000	-0.000	-0.000		
10	RE	5 0	NO		1.300+01	-0.000	-0.000	-0.000	-0.000		
10	RE	ADDITIONAL	VALUES		1.500+01	2.100+01	3.000+01	-0.000	-0.000		
11	F	6 5	NO		5.700+01	-0.000	-0.000	-0.000	-0.000	4 RB	0.000
11	F	ADDITIONAL	VALUES		5.600+01	5.400+01	5.000+01	-0.000	-0.000		
12	RDS	3 2	NO		1.000+06	-0.000	-0.000	-0.000	-0.000		
13	D(ID)	2 3			1.250-03	VALUE DETERMINED BY EQUATION 12					
14	VS	0 7	NO		1.200+01	-0.000	-0.000	-0.000	-0.000		1.000+00

THE EQUATIONS BELOW ARE EQUIN RELATIONSHIPS DESCRIBING THE PARTICULAR CIRCUIT ELEMENTS ABOVE .

```
12   INPUT=CARD(1)*((1.,0.)-(CARD(2)-VOLT(2))/CARD(3))**2
```

F.5a Special Solutions of V_{out} Versus V_{in}

DC ANALYSIS, SPCL SOLUTION, TITLED FIRST SPECIAL SOLUTION RVIN= 5

CIRCUIT ELEMENT VALUES FOR SPECIAL SOLUTIONS

NO.	TYPE	REAL PART	IMAGINARY PART
1	RIDSS	5.0000-03	0.0000
2	RVIN	5.0000+00	0.0000
3	RVP	2.0000+00	0.0000
4	RB	8.6000+02	0.0000
5	R2	4.0000+03	0.0000
6	R3	8.0000+02	0.0000
7	R4	2.0000+03	0.0000
8	VBE	-6.5000-01	0.0000
9	RD	1.0000+05	0.0000
10	RE	1.5000+01	0.0000
11	F	5.6000+01	0.0000
12	RDS	1.0000+06	0.0000
13	D(ID)	-3.1250-04	-0.0000
14	VS	-1.2000+01	0.0000

THE CIRCUIT ELEMENT VALUES BELOW WERE OBTAINED BY USING THE FIRST APPROXIMATION FOR THE DEPENDENT NODE VOLTAGES ENTERED ON DATA CARDS. THESE APPROXIMATIONS, WITH THEIR UPPER AND LOWER LIMITS, WERE

NODE	FIRST APPROX.	UPPER LIMIT	LOWER LIMIT	TOLERANCE
2	3.500000+00	5.000000+00	3.000000+00	2.000000-02

CIRCUIT ELEMENT VALUES FOR THE FIRST NONLINEAR SOLUTION.

NO.	TYPE	REAL VALUE	IMAGINARY VALUE
1	RIDSS	4.9999999-03	0.0000000
2	RVIN	5.0000000+00	0.0000000
3	RVP	2.0000000+00	0.0000000
4	RB	8.6000000+02	0.0000000
5	R2	4.0000000+03	0.0000000
6	R3	8.0000000+02	0.0000000
7	R4	2.0000000+03	0.0000000
8	VBE	6.5000000-01	0.0000000
9	RD	1.0000000+05	0.0000000
10	RE	1.5000000+01	0.0000000
11	F	5.5999999+01	0.0000000
12	RDS	1.0000000+06	0.0000000
13	D(ID)	-3.1249999-04	-0.0000000
14	VS	-1.2000000+01	0.0000000

VOLTAGES OBTAINED FROM USING THE ABOVE CIRCUIT ELEMENT VALUES IN THE CIRCUIT WERE

NODE	VOLTAGE OBTAINED
1	0.0000000
2	1.0677167+01
3	6.4857892-01
4	-1.4193140-03
5	9.5039827-05
6	1.0670690+01
7	1.1999669+01

```
NODE 2,HAS OUTPUT   3.450000+00,WITH GUESS OF   3.500000+00,DELTA FROM LAST GUESS= -5.000000-02
NODE 2,HAS OUTPUT   1.704012+01,WITH GUESS OF   3.450000+00,DELTA FROM LAST GUESS= -5.000000-02
NODE 2,HAS OUTPUT   1.394237+01,WITH GUESS OF   3.475000+00,DELTA FROM LAST GUESS=  2.500000-02
NODE 2,HAS OUTPUT   7.244525+00,WITH GUESS OF   3.525000+00,DELTA FROM LAST GUESS=  5.000000-02
NODE 2,HAS OUTPUT  -8.160514+00,WITH GUESS OF   3.625000+00,DELTA FROM LAST GUESS=  1.000000-01
NODE 2,HAS OUTPUT  -1.231064-01,WITH GUESS OF   3.575000+00,DELTA FROM LAST GUESS= -5.000000-02
NODE 2,HAS OUTPUT   1.394237+01,WITH GUESS OF   3.475000+00,DELTA FROM LAST GUESS= -1.000000-01
NODE 2,HAS OUTPUT   7.244525+00,WITH GUESS OF   3.525000+00,DELTA FROM LAST GUESS=  5.000000-02
NODE 2,HAS OUTPUT  -8.160514+00,WITH GUESS OF   3.625000+00,DELTA FROM LAST GUESS=  1.000000-01
NODE 2,HAS OUTPUT  -1.231064-01,WITH GUESS OF   3.575000+00,DELTA FROM LAST GUESS= -5.000000-02
NODE 2,HAS OUTPUT   1.394237+01,WITH GUESS OF   3.475000+00,DELTA FROM LAST GUESS= -1.000000-01
NODE 2,HAS OUTPUT   5.465412+00,WITH GUESS OF   3.537500+00,DELTA FROM LAST GUESS=  6.250000-02
NODE 2,HAS OUTPUT   8.344886-01,WITH GUESS OF   3.568750+00,DELTA FROM LAST GUESS=  3.125000-02
NODE 2,HAS OUTPUT   5.465412+00,WITH GUESS OF   3.537500+00,DELTA FROM LAST GUESS= -3.125000-02
NODE 2,HAS OUTPUT   3.182659+00,WITH GUESS OF   3.553125+00,DELTA FROM LAST GUESS=  1.562500-02
NODE 2,HAS OUTPUT   4.332207+00,WITH GUESS OF   3.545312+00,DELTA FROM LAST GUESS= -7.812500-03
NODE 2,HAS OUTPUT   3.759481+00,WITH GUESS OF   3.549219+00,DELTA FROM LAST GUESS=  3.906250-03
NODE 2,HAS OUTPUT   3.471581+00,WITH GUESS OF   3.551172+00,DELTA FROM LAST GUESS=  1.953125-03
NODE 2,HAS OUTPUT   3.615659+00,WITH GUESS OF   3.550195+00,DELTA FROM LAST GUESS= -9.765625-04
NODE 2,HAS OUTPUT   3.543652+00,WITH GUESS OF   3.550683+00,DELTA FROM LAST GUESS=  4.882812-04
```

DC ANALYSIS, SPCL SOLUTION, TITLED FIRST SPECIAL SOLUTION RVIN= 5

COMPUTED VOLTAGE OFF SELECTED NODES

NODE	MAGNITUDE
2	3.5471677+00
3	7.0272928-01
4	5.2698743-02
5	2.6432909-02
6	2.1583300+00
7	1.1997886+01

YOU HAVE REQUESTED THE VOLTAGE AT THE FOLLOWING NODES WHICH WERE ELIMINATED OR COMBINED WITH OTHER NODES ON CONVERSION TO THE EQUIVALENT CIRCUIT.
NODE 1

F.5b Special Solutions of V_{out} Versus V_{in}

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DC ANALYSIS, SPCL SOLUTION, TITLED            SECOND  SPECIAL SOLUTION RVIN= 7

                 CIRCUIT ELEMENT VALUES FOR SPECIAL SOLUTIONS

NO. TYPE  REAL PART  IMAGINARY PART

  1  RIDSS   5.0000-03    0.0000
  2  RVIN    7.0000+00    0.0000
  3  RVP     2.0000+00    0.0000
  4  RB      1.1700+03    0.0000
  5  R2      4.0000+03    0.0000
  6  R3      8.0000+02    0.0000
  7  R4      2.0000+03    0.0000
  8  VBE    -6.5000-01    0.0000
  9  RD      1.0000+05    0.0000
 10  RE      2.1000+01    0.0000
 11  F       5.4000+01    0.0000
 12  ROS     1.0000+06    0.0000
 13  D(ID)  -1.1250-04   -0.0000
 14  VS     -1.2000+01    0.0000

THE CIRCUIT ELEMENT VALUES BELOW WERE OBTAINED BY USING THE FIRST APPROXIMATION FOR THE DEPENDENT NODE VOLTAGES ENTERED
ON DATA CARDS. THESE APPROXIMATIONS, WITH THEIR UPPER AND LOWER LIMITS, WERE

NODE  FIRST APPROX.    UPPER LIMIT     LOWER LIMIT    TOLERANCE
  2    5.300000+00     7.000000+00     5.000000+00    2.000000-02

 CIRCUIT ELEMENT VALUES FOR THE FIRST NONLINEAR SOLUTION.

NO.  TYPE       REAL VALUE       IMAGINARY VALUE
  1  RIDSS      4.9999999-03      0.0000000
  2  RVIN       7.0000000+00      0.0000000
  3  RVP        2.0000000+00      0.0000000
  4  RB         1.1700000+03      0.0000000
  5  R2         4.0000000+03      0.0000000
  6  R3         8.0000000+02      0.0000000
  7  R4         2.0000000+03      0.0000000
  8  VBE        6.5000000-01      0.0000000
  9  RD         1.0000000+05      0.0000000
 10  RE         2.0999999+01      0.0000000
 11  F          5.4000000+01      0.0000000
 12  ROS        1.0000000+06      0.0000000
 13  D(ID)     -1.1249996-04     -0.0000000
 14  VS        -1.2000000+01      0.0000000

VOLTAGES OBTAINED FROM USING THE ABOVE CIRCUIT ELEMENT VALUES IN THE CIRCUIT WERE

  NODE     VOLTAGE OBTAINED
     1      0.0000000
     2      2.8866334+01
     3      4.5518645-01
     4     -1.9472485-01
     5     -9.3305600-02
     6      3.2351486+01
     7      1.2004215+01
NODE 2,HAS OUTPUT    5.270000+00,WITH GUESS OF    5.300000+00,DELTA FROM LAST GUESS= -2.999999-02
NODE 2,HAS OUTPUT    3.081365+01,WITH GUESS OF    5.270000+00,DELTA FROM LAST GUESS= -2.999999-02
NODE 2,HAS OUTPUT    2.986562+01,WITH GUESS OF    5.285000+00,DELTA FROM LAST GUESS=  1.500000-02
NODE 2,HAS OUTPUT    2.781581+01,WITH GUESS OF    5.315000+00,DELTA FROM LAST GUESS=  2.999999-02
NODE 2,HAS OUTPUT    2.310124+01,WITH GUESS OF    5.375000+00,DELTA FROM LAST GUESS=  5.999999-02
NODE 2,HAS OUTPUT    1.121233+01,WITH GUESS OF    5.495000+00,DELTA FROM LAST GUESS=  1.200000-01
NODE 2,HAS OUTPUT   -2.240460+01,WITH GUESS OF    5.735000+00,DELTA FROM LAST GUESS=  2.400000-01
NODE 2,HAS OUTPUT   -3.956288+00,WITH GUESS OF    5.615000+00,DELTA FROM LAST GUESS= -1.200000-01
NODE 2,HAS OUTPUT    2.310124+01,WITH GUESS OF    5.375000+00,DELTA FROM LAST GUESS= -2.400000-01
NODE 2,HAS OUTPUT    1.121233+01,WITH GUESS OF    5.495000+00,DELTA FROM LAST GUESS=  1.200000-01
NODE 2,HAS OUTPUT   -2.240460+01,WITH GUESS OF    5.735000+00,DELTA FROM LAST GUESS=  2.400000-01
NODE 2,HAS OUTPUT   -3.258783+00,WITH GUESS OF    5.610000+00,DELTA FROM LAST GUESS= -1.250000-01
NODE 2,HAS OUTPUT    2.435675+01,WITH GUESS OF    5.360000+00,DELTA FROM LAST GUESS= -2.500000-01
NODE 2,HAS OUTPUT    1.878738+01,WITH GUESS OF    5.422500+00,DELTA FROM LAST GUESS=  6.250000-02
NODE 2,HAS OUTPUT    4.979623+00,WITH GUESS OF    5.547500+00,DELTA FROM LAST GUESS=  1.250000-01
NODE 2,HAS OUTPUT    8.765186+00,WITH GUESS OF    5.516250+00,DELTA FROM LAST GUESS= -3.125000-02
NODE 2,HAS OUTPUT    6.900211+00,WITH GUESS OF    5.531875+00,DELTA FROM LAST GUESS=  1.562500-02
NODE 2,HAS OUTPUT    5.946874+00,WITH GUESS OF    5.539687+00,DELTA FROM LAST GUESS=  7.812500-03
NODE 2,HAS OUTPUT    4.979638+00,WITH GUESS OF    5.547500+00,DELTA FROM LAST GUESS=  7.812500-03
NODE 2,HAS OUTPUT    5.464990+00,WITH GUESS OF    5.543593+00,DELTA FROM LAST GUESS= -3.906250-03
NODE 2,HAS OUTPUT    5.706359+00,WITH GUESS OF    5.541640+00,DELTA FROM LAST GUESS= -1.953125-03
NODE 2,HAS OUTPUT    5.585787+00,WITH GUESS OF    5.542617+00,DELTA FROM LAST GUESS=  9.765625-04
NODE 2,HAS OUTPUT    5.525423+00,WITH GUESS OF    5.543105+00,DELTA FROM LAST GUESS=  4.882812-04

            DC ANALYSIS, SPCL SOLUTION, TITLED            SECOND  SPECIAL SOLUTION RVIN= 7

COMPUTED VOLTAGE OFF SELECTED NODES

NODE                      MAGNITUDE

  2                         5.5342642+00
  3                         7.0262084-01
  4                         5.2598631-02
  5                         2.6605513-02
  6                         4.5296530+00
  7                         1.1998382+01

          YOU HAVE REQUESTED THE VOLTAGE AT THE FOLLOWING NODES WHICH WERE ELIMINATED OR COMBINED WITH
OTHER NODES ON CONVERSION TO THE EQUIVALENT CIRCUIT.
NODE  1
```

F.5c Special Solutions of V_{out} Versus V_{in}

DC ANALYSIS, SPCL SOLUTION, TITLED THIRD SPECIAL SOLUTION RVIN= 9

CIRCUIT ELEMENT VALUES FOR SPECIAL SOLUTIONS

NO.	TYPE	REAL PART	IMAGINARY PART
1	RIDSS	5.0000-03	0.0000
2	RVIN	9.0000+00	0.0000
3	RVP	2.0000+00	0.0000
4	RB	1.5500+03	0.0000
5	R2	4.0000+03	0.0000
6	R3	8.0000+02	0.0000
7	R4	2.0000+03	0.0000
8	VBE	-6.5000-01	0.0000
9	RD	1.0000+05	0.0000
10	RE	3.0000+01	0.0000
11	F	5.0000+01	0.0000
12	RDS	1.0000+06	0.0000
13	D(ID)	-5.0000-05	-0.0000
14	VS	-1.2000+01	0.0000

THE CIRCUIT ELEMENT VALUES BELOW WERE OBTAINED BY USING THE FIRST APPROXIMATION FOR THE DEPENDENT NODE VOLTAGES ENTERED ON DATA CARDS. THESE APPROXIMATIONS, WITH THEIR UPPER AND LOWER LIMITS, WERE

NODE	FIRST APPROX.	UPPER LIMIT	LOWER LIMIT	TOLERANCE
2	7.200000+00	9.000000+00	7.000000+00	2.000000-02

CIRCUIT ELEMENT VALUES FOR THE FIRST NONLINEAR SOLUTION.

NO.	TYPE	REAL VALUE	IMAGINARY VALUE
1	RIDSS	4.9999999-03	0.0000000
2	RVIN	9.0000000+00	0.0000000
3	RVP	2.0000000+00	0.0000000
4	RB	1.5499999+03	0.0000000
5	R2	4.0000000+03	0.0000000
6	R3	8.0000000+02	0.0000000
7	R4	2.0000000+03	0.0000000
8	VBE	6.5000000-01	0.0000000
9	RD	1.0000000+05	0.0000000
10	RE	3.0000000+01	0.0000000
11	F	5.0000000+01	0.0000000
12	RDS	1.0000000+06	0.0000000
13	D(ID)	-4.9999963-05	-0.0000000
14	VS	-1.2000000+01	0.0000000

VOLTAGES OBTAINED FROM USING THE ABOVE CIRCUIT ELEMENT VALUES IN THE CIRCUIT WERE

NODE	VOLTAGE OBTAINED
1	0.0000000
2	3.0043510+01
3	3.5649371-01
4	-2.9340772-01
5	-1.4063990-01
6	3.3715059+01
7	1.2004510+01

```
NODE 2,HAS OUTPUT   7.180000+00,WITH GUESS OF   7.200000+00,DELTA FROM LAST GUESS= -2.000000-02
NODE 2,HAS OUTPUT   3.074678+01,WITH GUESS OF   7.180000+00,DELTA FROM LAST GUESS= -2.000000-02
NODE 2,HAS OUTPUT   3.040440+01,WITH GUESS OF   7.190000+00,DELTA FROM LAST GUESS=  9.999999-03
NODE 2,HAS OUTPUT   2.966411+01,WITH GUESS OF   7.210000+00,DELTA FROM LAST GUESS=  2.000000-02
NODE 2,HAS OUTPUT   2.796146+01,WITH GUESS OF   7.250000+00,DELTA FROM LAST GUESS=  4.000000-02
NODE 2,HAS OUTPUT   2.366779+01,WITH GUESS OF   7.330000+00,DELTA FROM LAST GUESS=  7.999999-02
NODE 2,HAS OUTPUT   1.152710+01,WITH GUESS OF   7.490000+00,DELTA FROM LAST GUESS=  1.600000-01
NODE 2,HAS OUTPUT  -2.696780+01,WITH GUESS OF   7.810000+00,DELTA FROM LAST GUESS=  3.200000-01
NODE 2,HAS OUTPUT  -5.351434+00,WITH GUESS OF   7.650000+00,DELTA FROM LAST GUESS= -1.600000-01
NODE 2,HAS OUTPUT   2.366779+01,WITH GUESS OF   7.330000+00,DELTA FROM LAST GUESS= -3.200000-01
NODE 2,HAS OUTPUT   2.615905+00,WITH GUESS OF   7.580000+00,DELTA FROM LAST GUESS=  2.500000-01
NODE 2,HAS OUTPUT   1.458771+01,WITH GUESS OF   7.455000+00,DELTA FROM LAST GUESS= -1.250000-01
NODE 2,HAS OUTPUT   8.963284+00,WITH GUESS OF   7.517500+00,DELTA FROM LAST GUESS=  6.250000-02
NODE 2,HAS OUTPUT   5.879962+00,WITH GUESS OF   7.548750+00,DELTA FROM LAST GUESS=  3.125000-02
NODE 2,HAS OUTPUT   7.444214+00,WITH GUESS OF   7.533125+00,DELTA FROM LAST GUESS= -1.562500-02
NODE 2,HAS OUTPUT   8.209385+00,WITH GUESS OF   7.525312+00,DELTA FROM LAST GUESS= -7.812500-03
NODE 2,HAS OUTPUT   7.828218+00,WITH GUESS OF   7.529219+00,DELTA FROM LAST GUESS=  3.906250-03
NODE 2,HAS OUTPUT   7.636569+00,WITH GUESS OF   7.531172+00,DELTA FROM LAST GUESS=  1.953125-03
NODE 2,HAS OUTPUT   7.540492+00,WITH GUESS OF   7.532148+00,DELTA FROM LAST GUESS=  9.765625-04
```

DC ANALYSIS, SPCL SOLUTION, TITLED THIRD SPECIAL SOLUTION RVIN= 9

COMPUTED VOLTAGE OFF SELECTED NODES

NODE	MAGNITUDE
2	7.5363199+00
3	6.9426128-01
4	4.4247586-02
5	2.3024034-02
6	6.9374715+00
7	1.1998885+01

YOU HAVE REQUESTED THE VOLTAGE AT THE FOLLOWING NODES WHICH WERE ELIMINATED OR COMBINED WITH OTHER NODES ON CONVERSION TO THE EQUIVALENT CIRCUIT.
NODE 1

APPENDIX G

RELATIONSHIPS FOR MONTE CARLO ANALYSIS

RELATIONSHIPS FOR MONTE CARLO ANALYSIS

Table G-1 lists a series of intervals at three confidence levels relating sample size to frequency of occurrence beyond particular limits.

As an example, consider an amplifier built from a random sampling of parts. If a Monte Carlo analysis is conducted with a sample size of 100, and if a 6 percent of the amplifiers fail to meet the defined limits, it can be statistically inferred with 95 percent confidence from Table G-1 that from 2 to 12 percent of an infinite number of amplifiers will fall outside the defined limits. It can also be stated with 90 percent confidence that from 3 to 11 percent will fail to meet specifications; or with 99 percent confidence that 2 to 14 percent will fail to meet specifications.

As a further illustration, assume a sample size of 1000 of the same amplifier. If 6 percent fall outside the specified limits, it can be stated with 90 percent confidence that between 5 and 7 percent of an infinite population will fail to meet specifications.

If a single-valued estimate rather than an interval is required, the tabulated data take on confidence levels of 95, 97-1/2, and 99-1/2 percent instead of 90, 95, and 99 percent, respectively. For 1000 amplifiers having 6 percent failures, it can be said with 95 percent confidence that less than 7 percent of an infinite population will fail--or, conversely, that <u>more</u> than 5 percent will fail.

Table G-2 may be useful when deciding the proper sample size, knowing an acceptable sample mean, tolerance and confidence level. For example, if we require the numerical value of the mean, to within 5 percent with 99 percent confidence, 660 iterations are necessary.

TABLE G-1. SAMPLE SIZE VS. FREQUENCY OF OCCURRENCE

Percent of Sample Beyond Established Limits / Sample →	90% Confidence 50	90% Confidence 100	90% Confidence 1000	95% Confidence 50	95% Confidence 100	95% Confidence 1000	99% Confidence 50	99% Confidence 100	99% Confidence 1000
	Range of Failures (Percent) to be Expected for Infinite Population, for Various Sample Sizes and Confidence Levels								
0	0 6	0 3	0 1	0 7	0 4	0 1	0 10	0 5	0 1
1		0 4	0 2		0 5	0 2		0 7	0 2
2	0 8	1 5	1 3	0 11	0 7	1 3	0 14	0 9	1 3
3		1 7	2 4		1 8	2 4		0 10	2 4
4	1 11	2 8	3 5	0 14	1 10	3 5	0 17	1 12	3 6
5		3 9	4 6		2 11	4 7		1 13	3 7
6	2 14	3 11	5 7	1 17	2 12	5 8	1 20	2 14	4 8
7		4 12	6 9		3 14	6 9		2 16	5 9
8	3 17	5 14	7 10	2 19	4 15	6 10	1 23	3 17	6 10
9		5 15	8 11		4 16	7 11		3 18	7 12
10	4 19	6 16	9 12	3 22	5 18	8 12	2 26	4 19	8 13
11		7 17	10 13		5 19	9 13		4 20	9 14
12	5 22	8 18	11 14	5 24	6 20	10 14	3 29	5 21	9 15
13		9 19	12 15		7 21	11 15		6 23	10 16
14	7 24	9 21	13 16	6 27	8 22	12 16	4 31	6 24	11 17
15		10 22	13 17		9 24	13 17		7 26	12 18
16	8 27	11 23	14 18	7 29	9 25	14 18	6 33	8 27	13 19
17		12 24	15 19		10 26	15 19		9 29	14 20
18	9 29	13 25	16 20	9 31	11 27	16 21	7 36	9 30	15 21
19		13 26	17 21		12 28	17 22		10 31	16 22
20	11 31	14 27	18 22	10 34	13 29	18 23	8 38	11 32	17 23

TABLE G-2. SAMPLE SIZE VS. MEAN/TOLERANCE/ CONFIDENCE LEVEL

Percent Tolerance of Sample Mean	Sample Size or Number of Iterations Required for:		
	90% Confidence Level	95% Confidence Level	99% Confidence Level
1	6,800	9,600	16,500
2	1,700	2,400	4,125
3	750	1,066	1,833
5	272	384	660
10	68	96	165
20	17	24	38